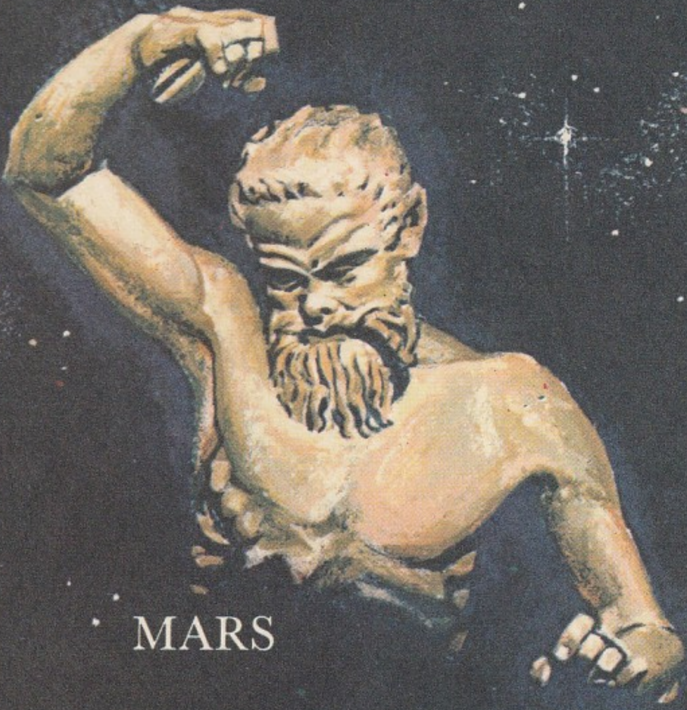
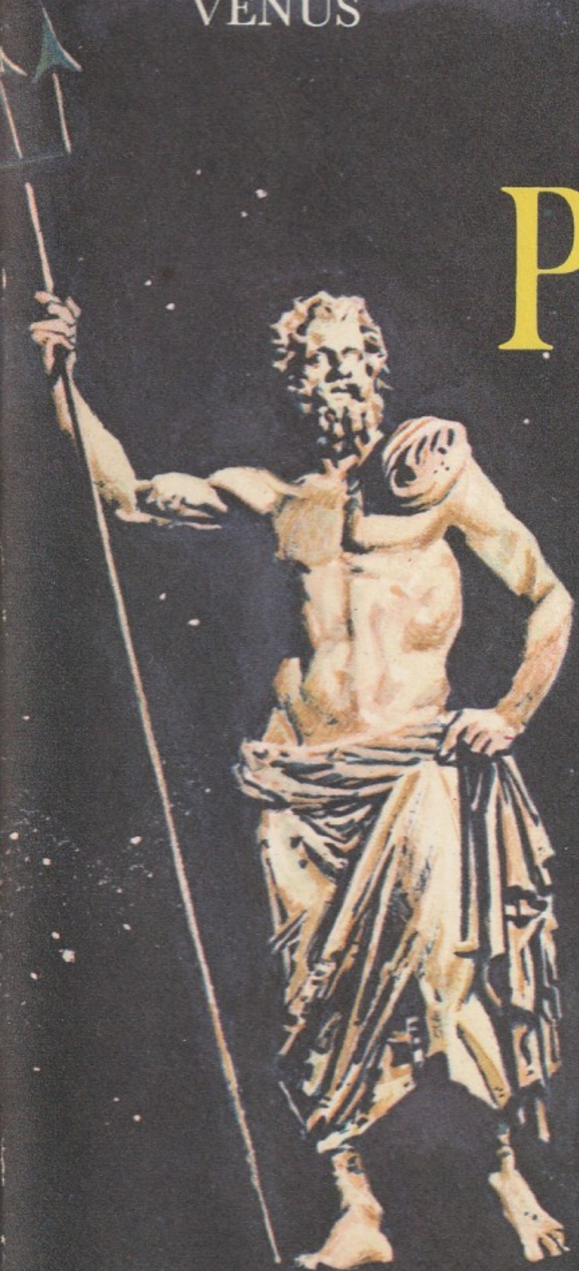
VENUS

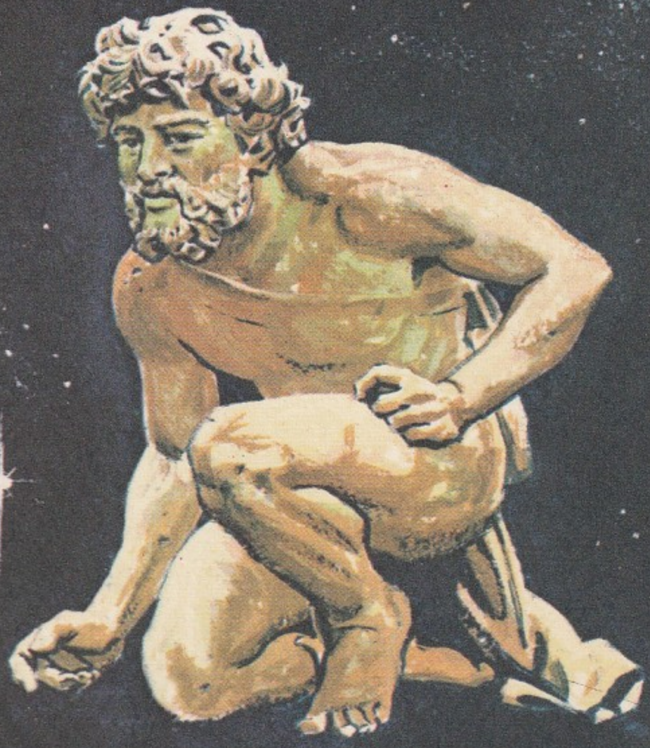


MARS

PLANETS



NEPTUNE



PLUTO

SCIENCE SERVICE

SCIENCE PROGRAM

201433
4

PLANETS

SCIENCE PROGRAM

Prepared with the co-operation of
Science Service

COPYRIGHT © 1968 BY NELSON DOUBLEDAY, INC.

PUBLISHED BY NELSON DOUBLEDAY, INC. AND ODHAMS BOOKS LTD.
PRINTED IN THE UNITED STATES OF AMERICA

Wanderers in the Sky

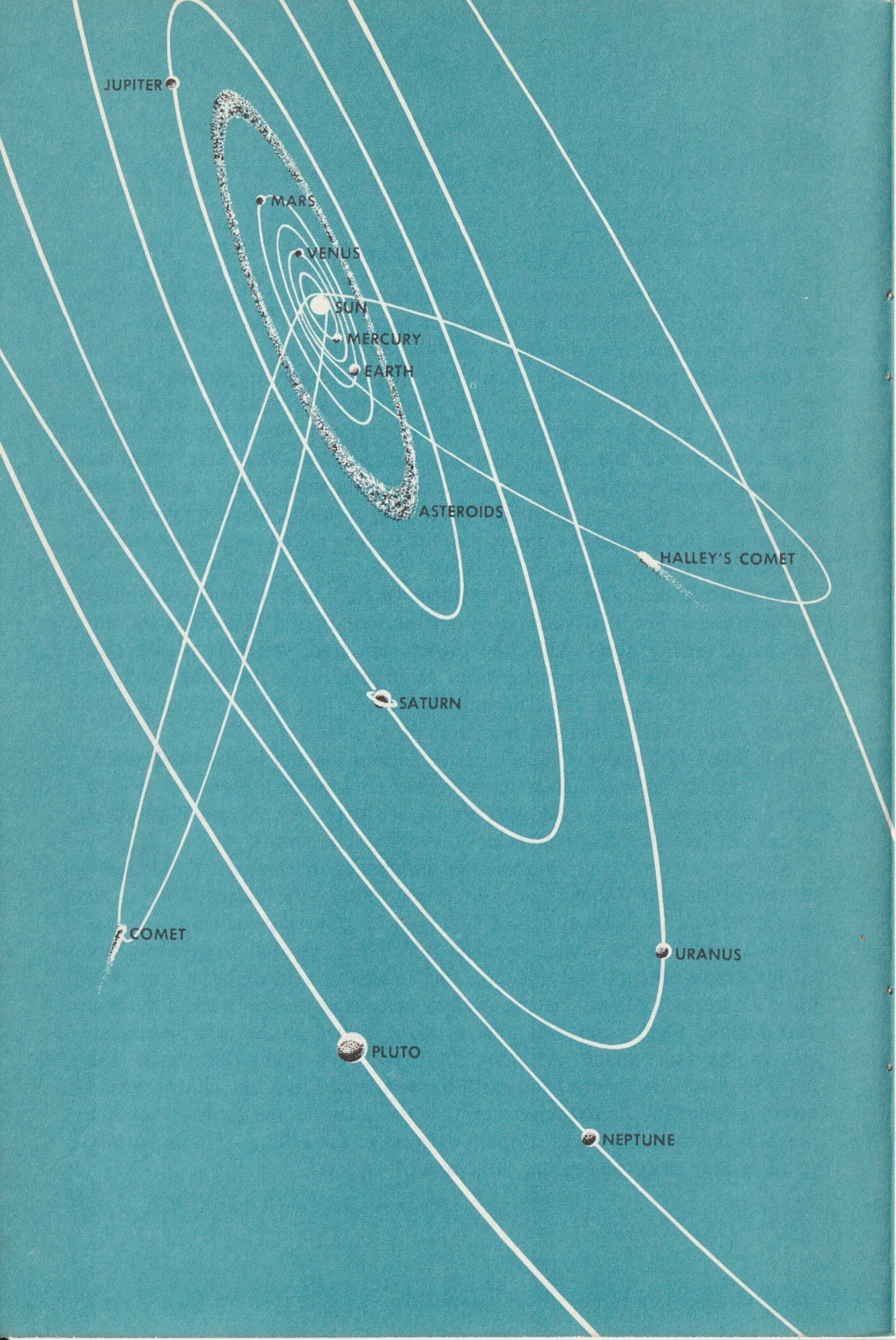
ARE YOU A PLANET-GAZER—one who can peer at the heavens and tell within minutes the difference between Venus or Mars and the surrounding stars? All it takes is a little experience.

Everybody knows that the stars in the sky form certain patterns, called constellations. If you are used to recognizing the star patterns, you'll soon notice there are a few "stars" which do not stay put. Slowly but noticeably they move out of one star pattern and into another. The "stars" that do this usually are bright. People realized early that these were a special sort of "star" and the ancient Greeks gave them a name. Since they did not stay in one place as all the others did, the Greeks called them "wanderers" —*planētēs* in their language.

We still use the name *planets* for these "stars", and we now know they are not stars. The real stars are luminous hot bodies like our own sun but much farther away, while the planets are cold, which is to say that they do not make their own light but shine instead by reflecting sunlight. All the planets we see move around the sun, a fact some of the ancient Greeks had guessed, but did not attempt to prove.

It is interesting that the planets move around the sun in the same direction. If you could watch their movement from a point a thousand million miles above the North Pole, you would see that they all move counterclockwise, like the hands of a clock running backwards.

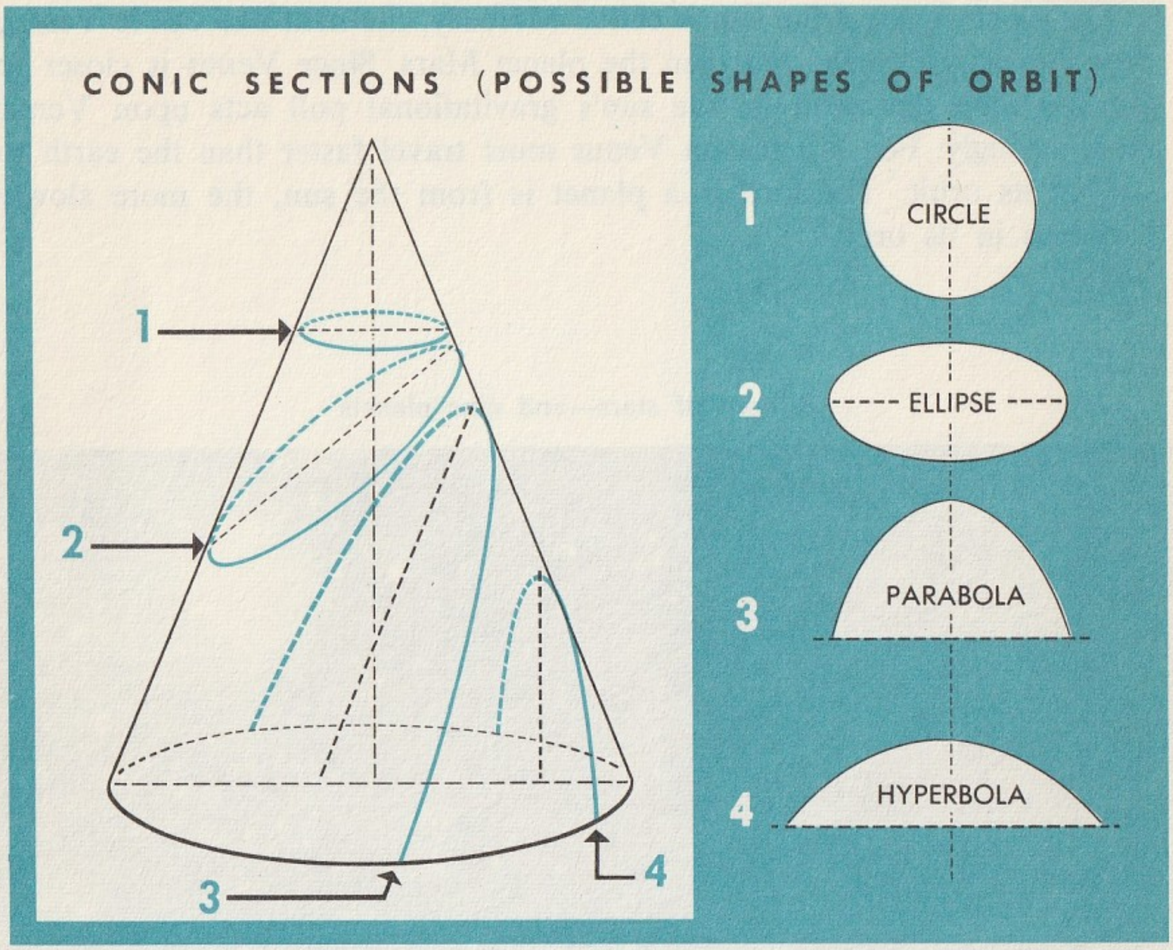
Another interesting point about the motion of the planets is that none of them rises much above the orbit of any other (the planet Pluto is an exception which will be discussed later) nor do they dip far below. If you make a model of the solar system in which the sun and the planets are all little balls of cork and you float the model in a large basin, you will have a true picture; just as the cork planets stay on the water's surface and none of them jumps out of it or dives below, so the real planets all stay in the same plane. Actually, there are very slight deviations, and for that reason the orbit of the earth is considered the norm (the technical name is *ecliptic*). Astronomers say that the plane of the orbit of another planet is inclined by so and so many degrees to the ecliptic. The important point is that these angles are very small.


JUPITER
MARS
VENUS
SUN
MERCURY
EARTH
ASTEROIDS
HALLEY'S COMET
SATURN
COMET
URANUS
PLUTO
NEPTUNE

The planet nearest the sun is called Mercury, the next one out is Venus, then comes our earth, and then the planet Mars. Since Venus is closer to the sun than the earth is, the sun's gravitational pull acts upon Venus more strongly. For this reason Venus must travel faster than the earth to stay in its orbit. The farther a planet is from the sun, the more slowly it moves in its orbit.

Billions of stars—and nine planets

CONIC SECTIONS (POSSIBLE SHAPES OF ORBIT)



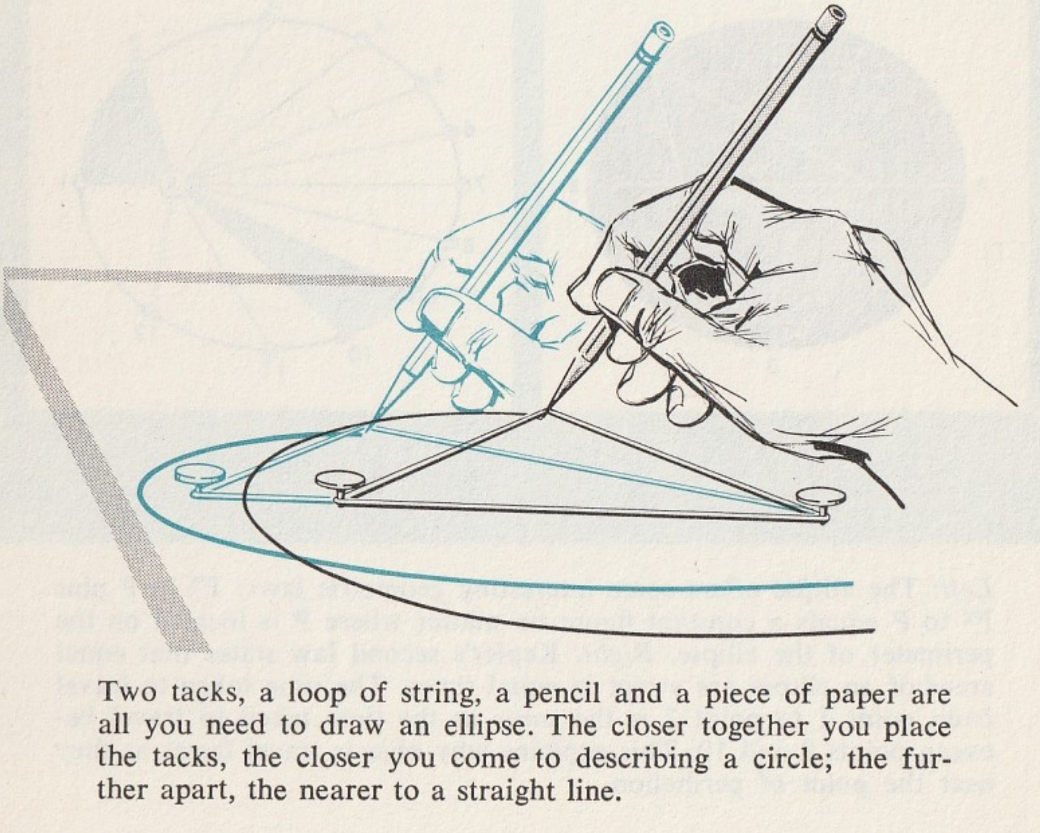
Other Bodies in the Solar System

ALTHOUGH THE PLANETS ARE THE MAIN MEMBERS of the solar system, they are not the only ones. To begin with, most planets have one or several moons which are solid bodies like the planets themselves but smaller in size. These moons do not move around the sun directly as the planets do; they move around the planets and are carried along by them around the sun.

Then there are quite small bodies, ranging in size from dust grains to large mountains, that move around the sun very much like the planets. But their orbits are such that they occasionally run into a planet. If they run into earth's atmosphere and they are the size of sand grains, the result is what we call a *shooting star*. If they are fist-sized, we say that we saw a *fireball*. If they are really large, they reach the earth's surface and make a large hole in the ground; that size we call a *meteorite*.

Finally there are the *comets,* which are members of our solar system too. What distinguishes a comet from a planet will be discussed later. At the moment we are mainly interested in the fact that the orbits of the comets are ellipses. They do not develop tails until they are at about the distance that Mars is from the sun. (They don't stay in the plane of the ecliptic either.) Some comets have a retrograde motion, which is quite unlike planets and asteroids, and this brings up the question of the various shapes that orbits can take in space.

Mathematicians speak about the *four conic sections,* the different shapes that can result when you cut through a cone in different directions. One of these shapes is the *ellipse* and another is the *circle,* which is a special kind of ellipse. The third and fourth are called the *parabola* and the *hyperbola* respectively. It so happens that a body moving through space must move along one of these curves. But the conditions necessary for an object to have a circular or parabolic orbit are so precise that they do not actually occur. In reality a body will either move in a closed orbit which would be an ellipse (as do all planets, all moons and most comets), or it might move along an open curve or hyperbola.



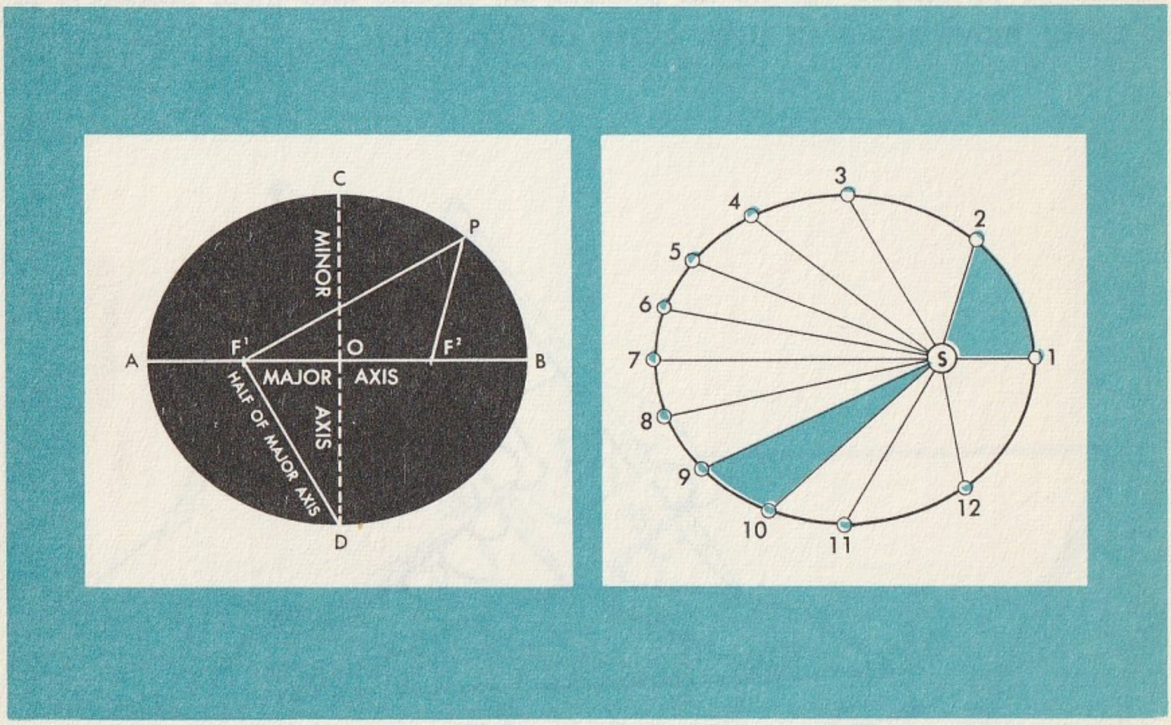
Two tacks, a loop of string, a pencil and a piece of paper are all you need to draw an ellipse. The closer together you place the tacks, the closer you come to describing a circle; the further apart, the nearer to a straight line.

What Is an Ellipse?

SINCE THE NORMAL ORBIT IS AN ELLIPSE, let's have a quick look at this curve. You understand it best if you draw one—this is easily done in the following way:

Stick two thumb tacks into a piece of cardboard, three or four inches apart. Put a loop of string around the tacks. The loop should be long enough so that the string is not taut but has a little slack. Pull the string out with a pencil, marking on the cardboard as you move the pencil around the two tacks until the circuit is completed. The pencil line makes an ellipse.

All the planets in their travels around the sun follow a path that is an ellipse. The velocity of the planet tends to move it away from the sun, but the pull of the sun keeps pulling it toward itself.



Left: The ellipse offers some interesting geometric laws: F^1 to P plus F^2 to P equals a constant figure no matter where P is located on the perimeter of the ellipse. *Right:* Kepler's second law states that equal areas of an ellipse are swept in equal times. The time taken to travel from point 1 to point 2 is the *same* as the time taken to travel between points 9 and 10. This explains why objects travel faster as they near the point of perihelion.

THE PLANETS

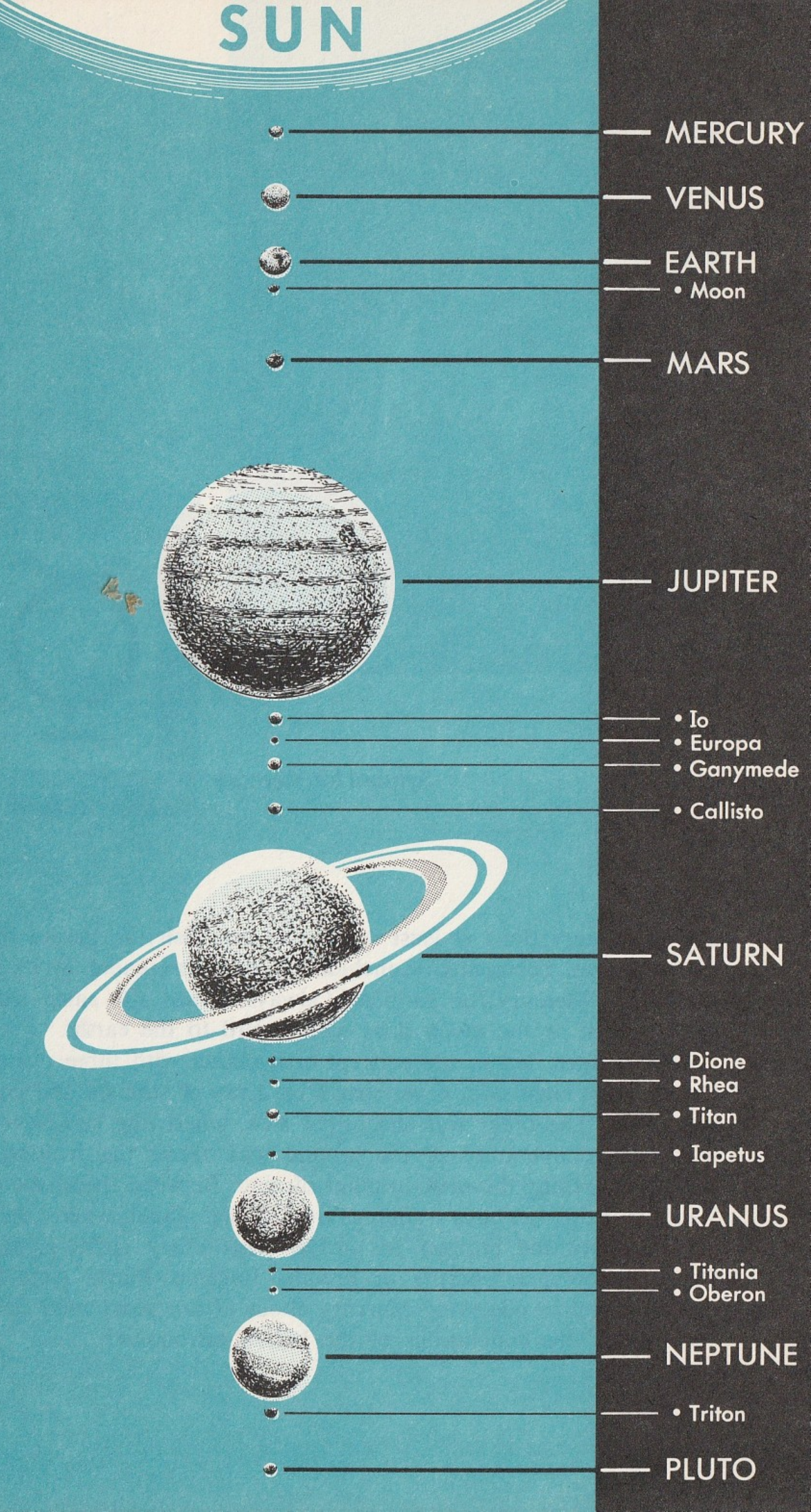
Name	Average distance from sun (millions of miles)	Planet's diameter (miles)	Length of year	Length of day	Mean orbital velocity (mi./sec.)	Your weight on planets (Multiply your weight by:)	Number of moons
Mercury	36.0	3,010	88.0 days	59 days	29.7	0.36	0
Venus	67.2	7,610	224.7 days	30 days(?)	22	0.87	0
Earth	92.9	7,918	365.26 days	23 hrs. 56 mins. 04 secs.	18.52	1.00	1
Mars	141.5	4,140	687 days	24 hrs. 37 mins. 23 secs.	15.0	0.38	2
Jupiter	483.4	86,900	11.86 years	9 hrs. 50 mins. 30 secs.	8.1	2.64	12
Saturn	886	71,500	29.46 years	10 hrs 14 mins.	6	1.13	9-10
Uranus	1,782	29,500	84.01 years	10 hrs. 49 mins.	4.22	1.07	5
Neptune	2,792	26,800	164.8 years	14 hrs.(?)	3.33	1.41	2
Pluto	3,664	8,700(?)	247.7 years	6.39 days(?)	2.94	?	?

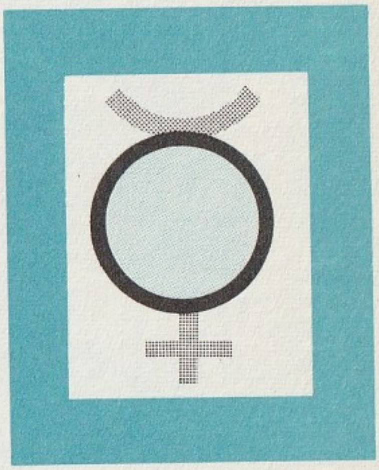
Mercury, the Smallest Planet

MERCURY, THE PLANET closest to the sun—its mean distance is thirty-six million miles—also happens to be the smallest of the planets. Its diameter is 3,010 miles, a little larger than our own moon (2,160 miles). For both these reasons Mercury is hard to see. In addition to being small it has a low *albedo,* or reflectivity, and therefore is not very bright. Because it is close to the sun, it rises only a short time ahead of the sun; or else it sets very soon after the sun sets. The result is that the sky around Mercury is always quite bright, and in order to find it you have to know just when and where to look.

For all these reasons, there has been much misinformation about Mercury. In fact, little at all was known about the planet until the Italian astronomer Giovanni Virginio Schiaparelli began to observe Mercury in daytime, about seventy-five years ago. He decided that observations in the daylight sky might bring better results than observations at twilight, since he would see the planet through a thinner layer of atmosphere. These

THE RELATIVE SIZES OF THE VARIOUS PLANETS





Symbol for Mercury

daylight observations at least seemed to establish the period of rotation of the planet. Schiaparelli concluded that it was equal to its period of revolution. Mercury, he surmised, always turned the same side toward the sun, just as the moon does with regard to the earth.

This, in turn, led to the concept of a planet with three distinct zones. One was the night side, never struck by a ray of sunlight and correspondingly cold. The other was the bright side, where the sun never set and where the temperature of the ground was above the melting point of lead, approaching the melting point of zinc. Between them, there was the "twilight belt", an area running around the planet where the sun appeared above the horizon for a few days every eighty-eight days. A Greek astronomer working in France, Eugenios-Marie Antoniadi, who spent much time observing Mercury about fifteen years after Schiaparelli, "confirmed" the conclusions of the Italian astronomer.

Now . . . the Truth

We now know, thanks to radar experiments carried out by the American astronomers Gordon H. Pettengill and Rolf Dyce in 1965, with the aid of the 1,000-foot radio-telescope at Arecibo, Puerto Rico, that Schiaparelli and Antoniadi were wrong. Mercury does rotate on its axis, and its period of rotation is two-thirds of its period of revolution, or about fifty-nine days. Hence, no permanent bright side, no permanent night side and no twilight belt. Every point of Mercury's

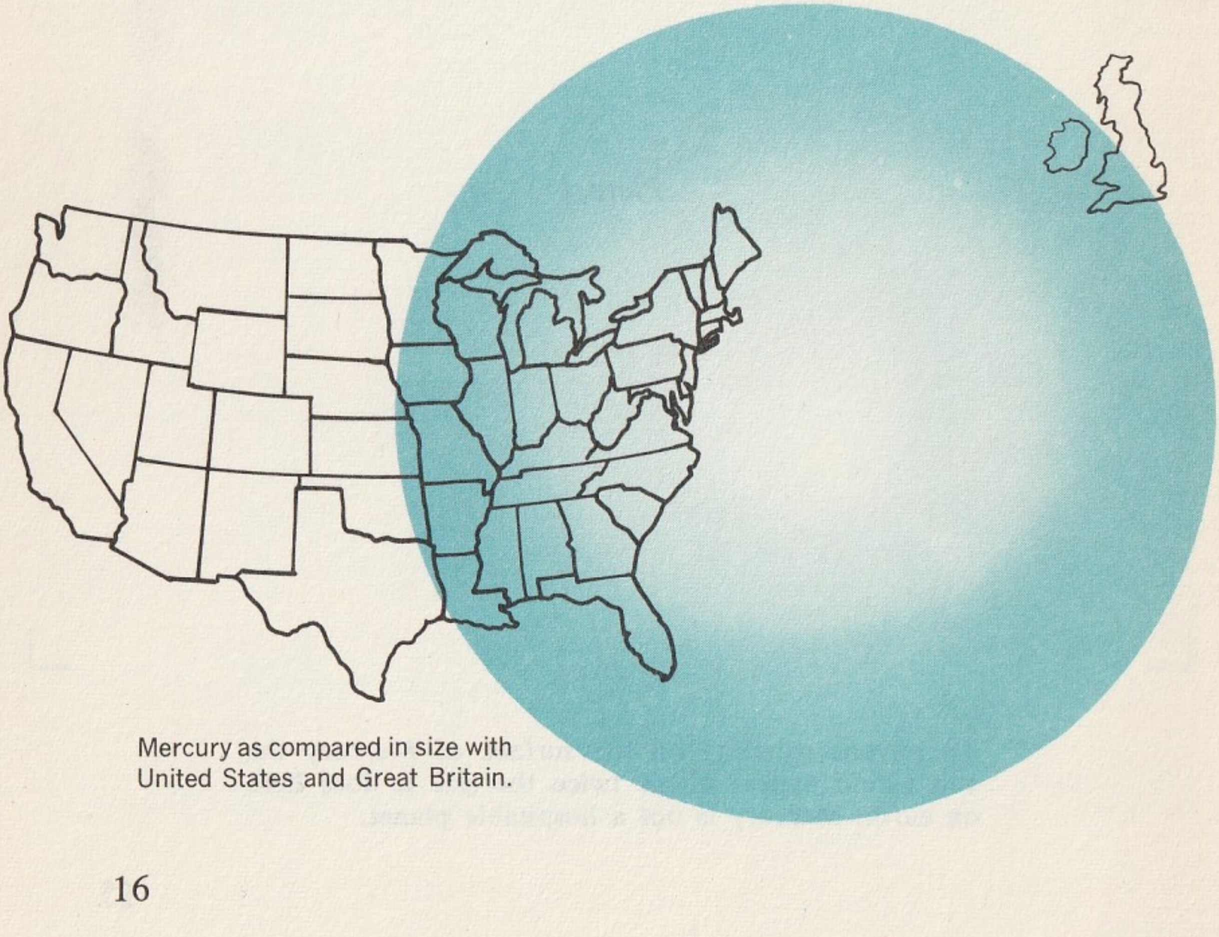
1. MERCURY

To anyone standing on the surface of Mercury the sun would appear about twice the size it does here on earth. Mercury is not a hospitable planet.

surface is illuminated and heated by the sun, and the hub of the area that happens to have "day" does heat up to about 660° F. Another American astronomer, Kenneth Kellerman, used the Parkes radio-telescope near Sydney, Australia, to measure the temperature of that portion of Mercury that happens to have night. Before this could be actually measured, it had been assumed that the temperature was approximately 350 degrees below zero. Kellerman found it to be about 30° F. or near the melting point of ice on earth. This result corresponds well with the slow rotation of the planet observed by the Arecibo telescope.

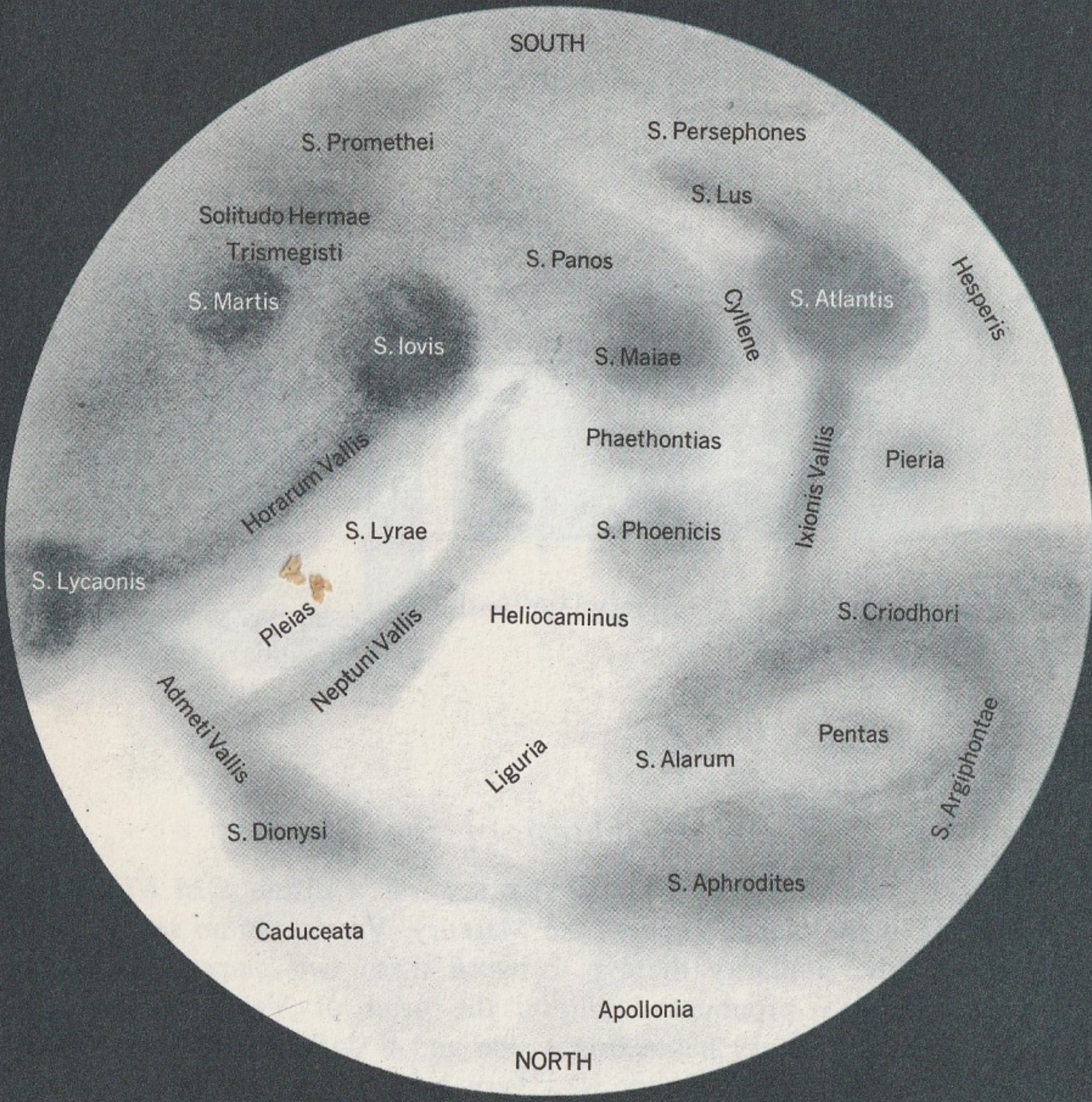
A Map of Mercury

In 1894 Schiaparelli, who also mapped the "canals" on Mars, made the first map of the face of Mercury. Since then, much better and more detailed maps have been made, but on all, the markings appear to be permanent and similar to those found on the moon.



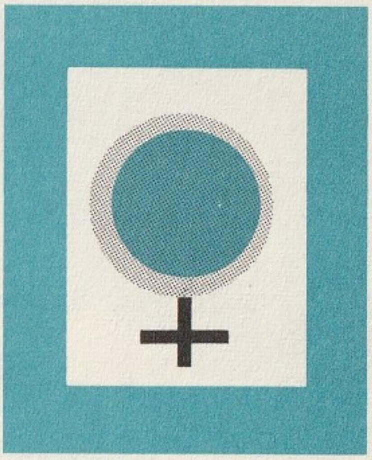
Mercury as compared in size with United States and Great Britain.

MAP OF MERCURY



Mercury through a telescope. Map is based on Antoniadi's observations.

Professor Audouin Dollfus of the Paris Astronomical Observatory, one of the world's foremost authorities on Mercury, says that it is likely that many of the spots seen on Mercury have the same origins as the lunar *maria,* the so-called seas found on the moon. As with the moon, Mercury must be pockmarked with craters resulting from volcanic action or many impacts of meteorites or small asteroids, or from both causes.



Symbol for Venus

Venus, Brightest of the Planets

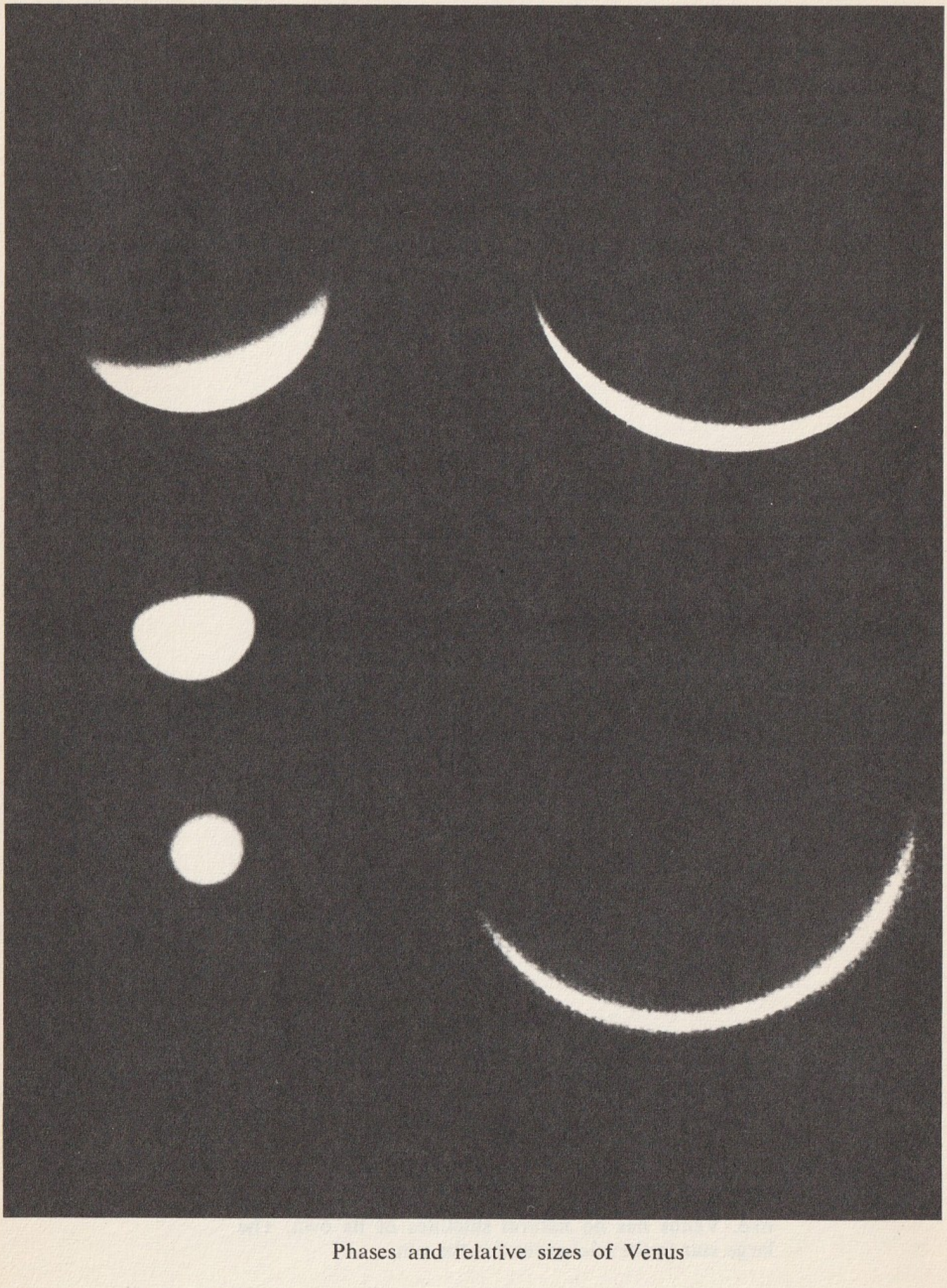
THE NEXT PLANET OUT FROM THE SUN, at a distance of 67 million miles, is the planet Venus. Like Mercury, Venus has no satellite, but that is all the similarity there is between these two planets. Mercury's orbit is a fairly pronounced ellipse, the orbit of Venus is almost a precise circle. Mercury has a bright side and a dark side, Venus is very nearly white in hue. Mercury is a very small planet, Venus is nearly the size of the earth. Mercury is hard to see; Venus, when appearing as morning or evening star, is so bright that of all the objects in the sky only the full moon (and, of course, the sun) are brighter.

Venus is so bright, in fact, that it occasionally has caused concern among people who are not familiar with the sky. A hundred years ago Venus shone so brilliantly in the western sky that the commander of the French naval forces at Boulogne ordered a gunboat to put to sea, investigate and take action, if necessary. During World War I Venus was shining so brightly over the midwestern plains of the United States that some people concluded it had to be a German airship. During the last ten years Venus, as morning star, has been reported as a "flying saucer" so many times that the authorities have given up counting. At times of greatest brilliancy, Venus is fifteen times brighter than Sirius, the brightest star, and can be seen with the naked eye at midday if you know just where to look. At night, the light from Venus, when it is at its brightest, can cast a shadow of objects on earth.

Since Venus is covered by clouds from pole to pole, there are no visible surface markings and we cannot tell how fast Venus rotates. For many years astronomers who specialize in the planets have agreed on "about one month" as a likely figure, but in most tables of planetary statistics, any figure given for the period of rotation of Venus is followed by a question mark.

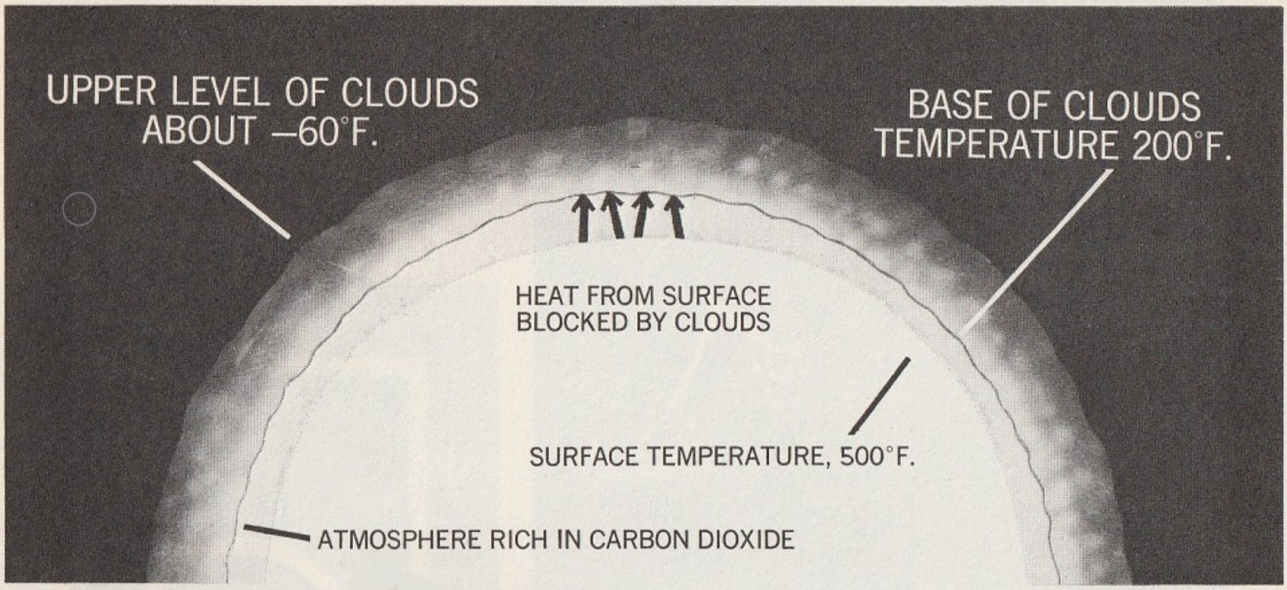
2. VENUS

This is an artist's conception of what Venus looks like. Venus has no natural satellites of its own. The large star in the background is the sun.



Phases and relative sizes of Venus

"Greenhouse Effect" on Venus

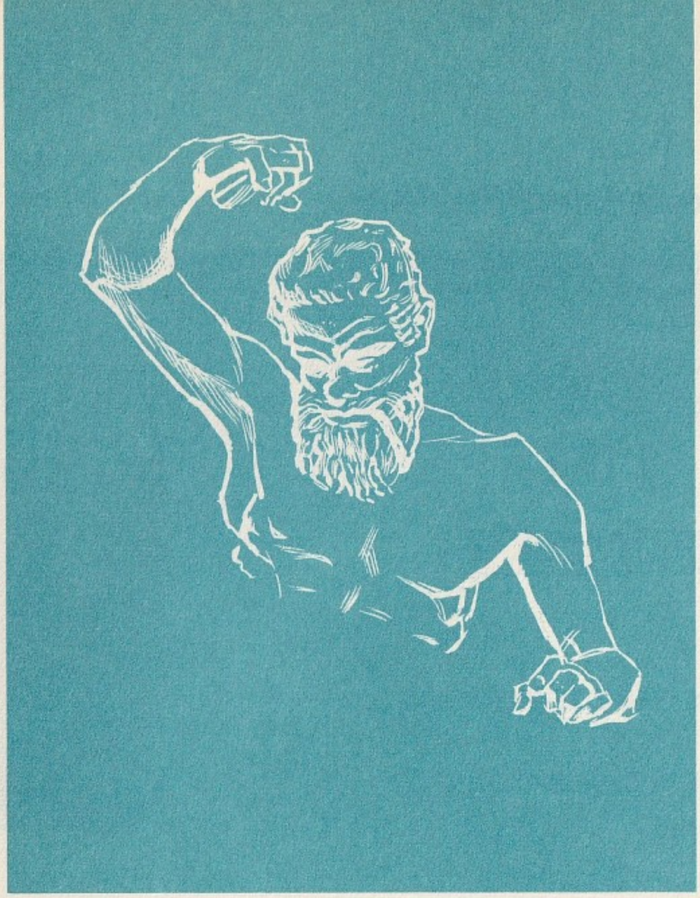


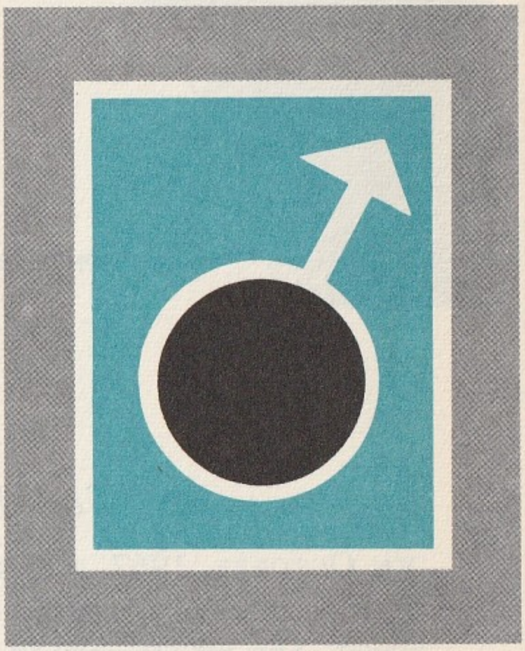
Too Hot to Support Life

In October, 1967, a Russian space probe landed on Venus, and America's Mariner V passed within 2,500 miles in a dual exploration of the planet. The results showed a hot, dense atmosphere and a surface that is rough and dry, with a temperature of more than 500° Fahrenheit—hot enough to melt tin. The atmospheric pressure of Venus is considerably greater than earth's, perhaps fifteen times greater, and made up mostly of carbon dioxide. The cloud layer begins about forty-five miles above the surface and extends upward about twenty miles.

The knowledge that the surface temperature of Venus is so high shattered the ages-old theory that there may be life on the planet. A temperature of 500° F. is much too hot to allow the development of life, except possibly at the poles, and even that is uncertain.

Why is Venus so hot? Scientists refer to a "greenhouse effect"—the result of the planet's very dense atmosphere. In the case of earth, most of the surface heat escapes into space. With Venus it is different. Its atmosphere, containing large amounts of carbon dioxide and water vapour, traps the planet's heat and sends it back to the surface. This raises the temperature of the surface considerably above the level it would have been if Venus were an airless rock.





Symbol for Mars

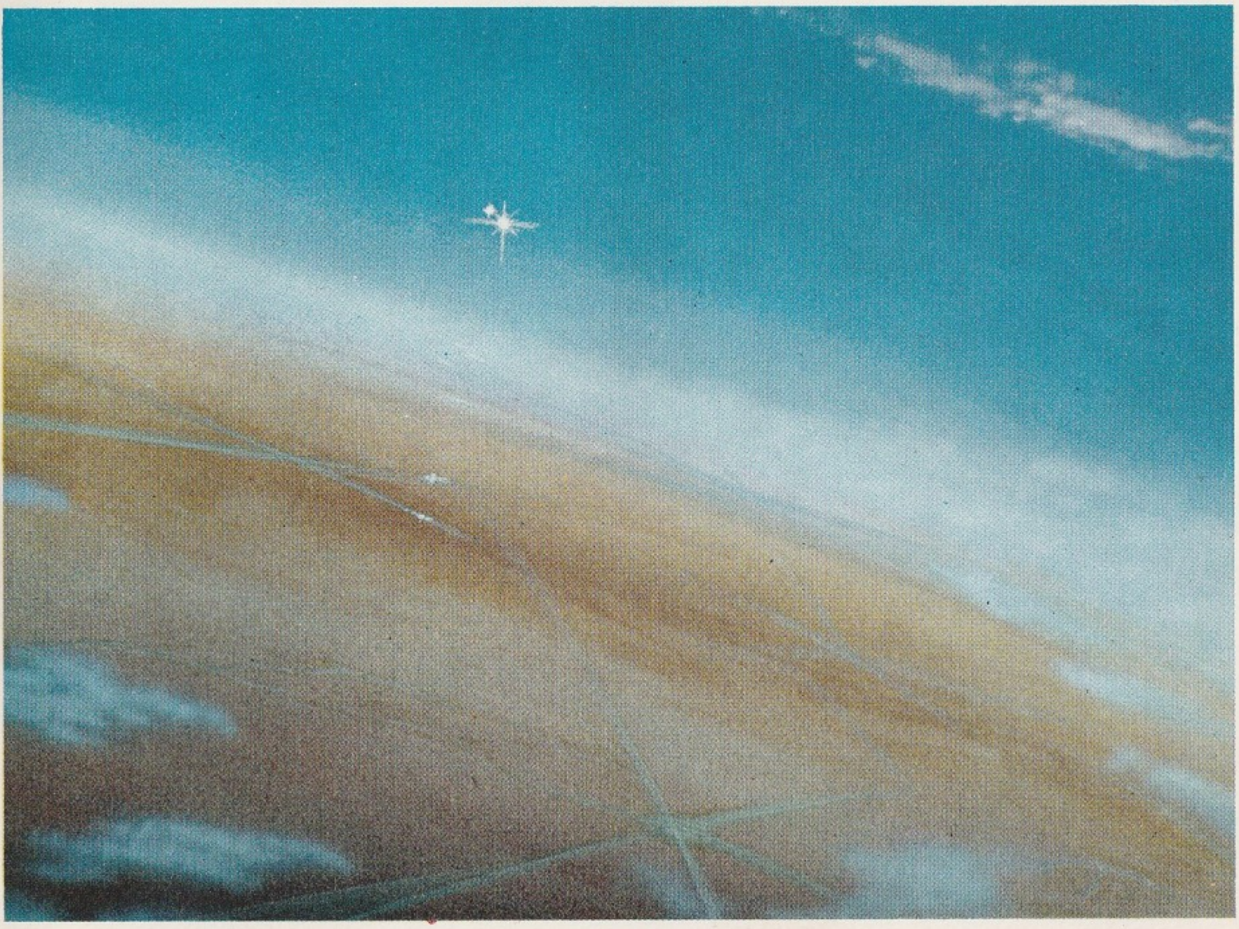
Mars—Outside Earth's Orbit

THE FIRST PLANET beyond the orbit of the earth is Mars. Though only about half the size of the earth it is rather earthlike in many respects—but this means principally that it is less different from the earth than the other planets. Mars is a distinct red or rust in hue, when viewed from earth.

Mars turns on its axis at about the same rate as the earth, but its day lasts a little longer, namely twenty-four hours, thirty-seven minutes and twenty-three seconds. To complete one orbit around the sun it needs 687 earth-days, but a man on Mars would say that the year lasts 668.6 (Martian) days. At any event the Martian year is not quite two earth-years, and for this reason the faster-moving earth overtakes Mars at regular intervals, on the average every two years and two months.

Then the earth and Mars, as seen from the sun, are in the same part of the heavens and it is at those times that we can see Mars best.

Astronomers call these times *oppositions* because (as seen from the earth) Mars is on one side and the sun is on the other side. But one opposition is not as good as every other for observing the planet because the orbit of Mars is a fairly pronounced ellipse. When Mars is at *perihelion,* that is, closest to the sun, it is 128 million miles from it. At that time its orbital velocity is 16.45 miles per second. When Mars is at *aphelion,* that is, farthest from the sun, it is 154.1 million miles



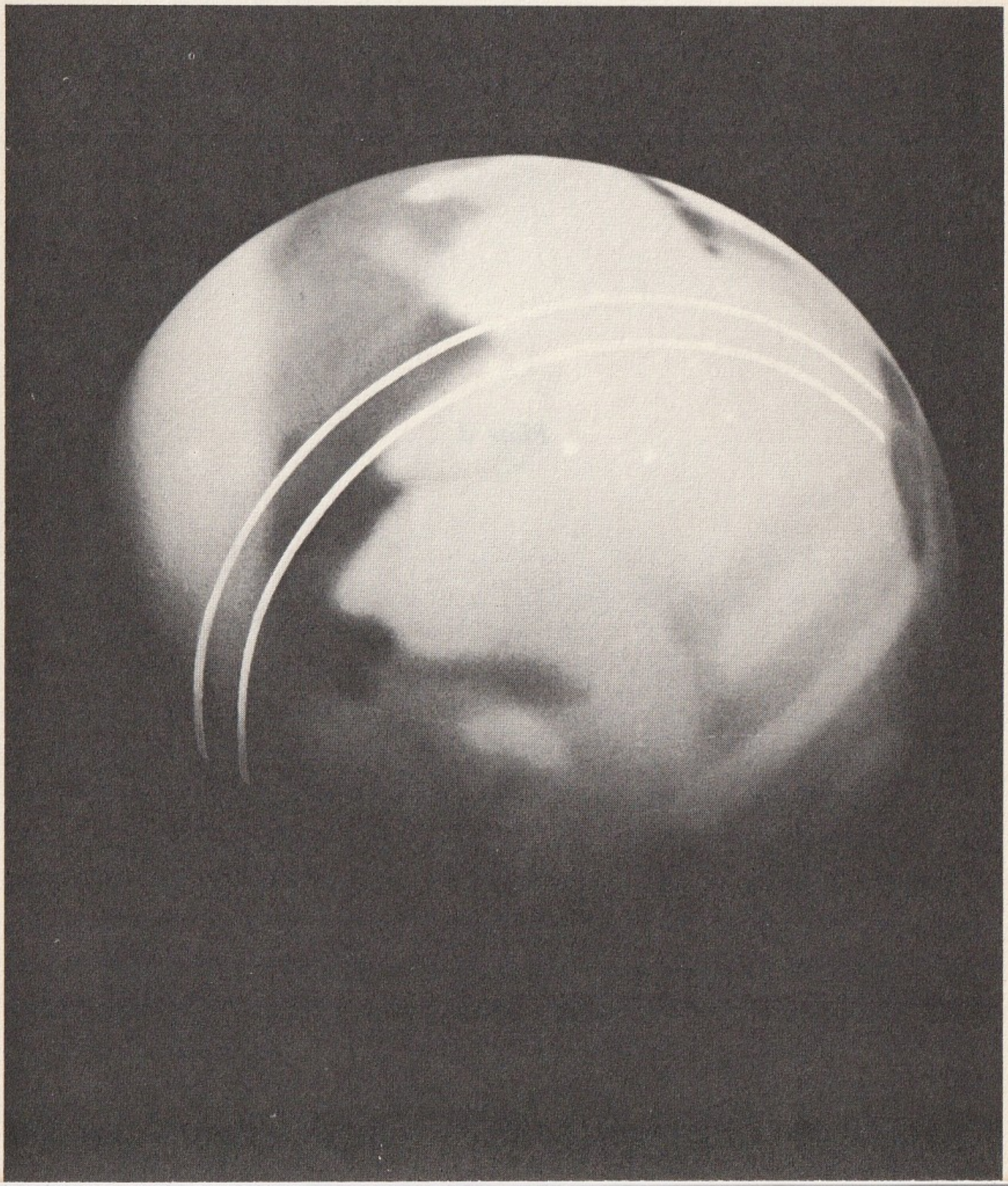
3. MARS

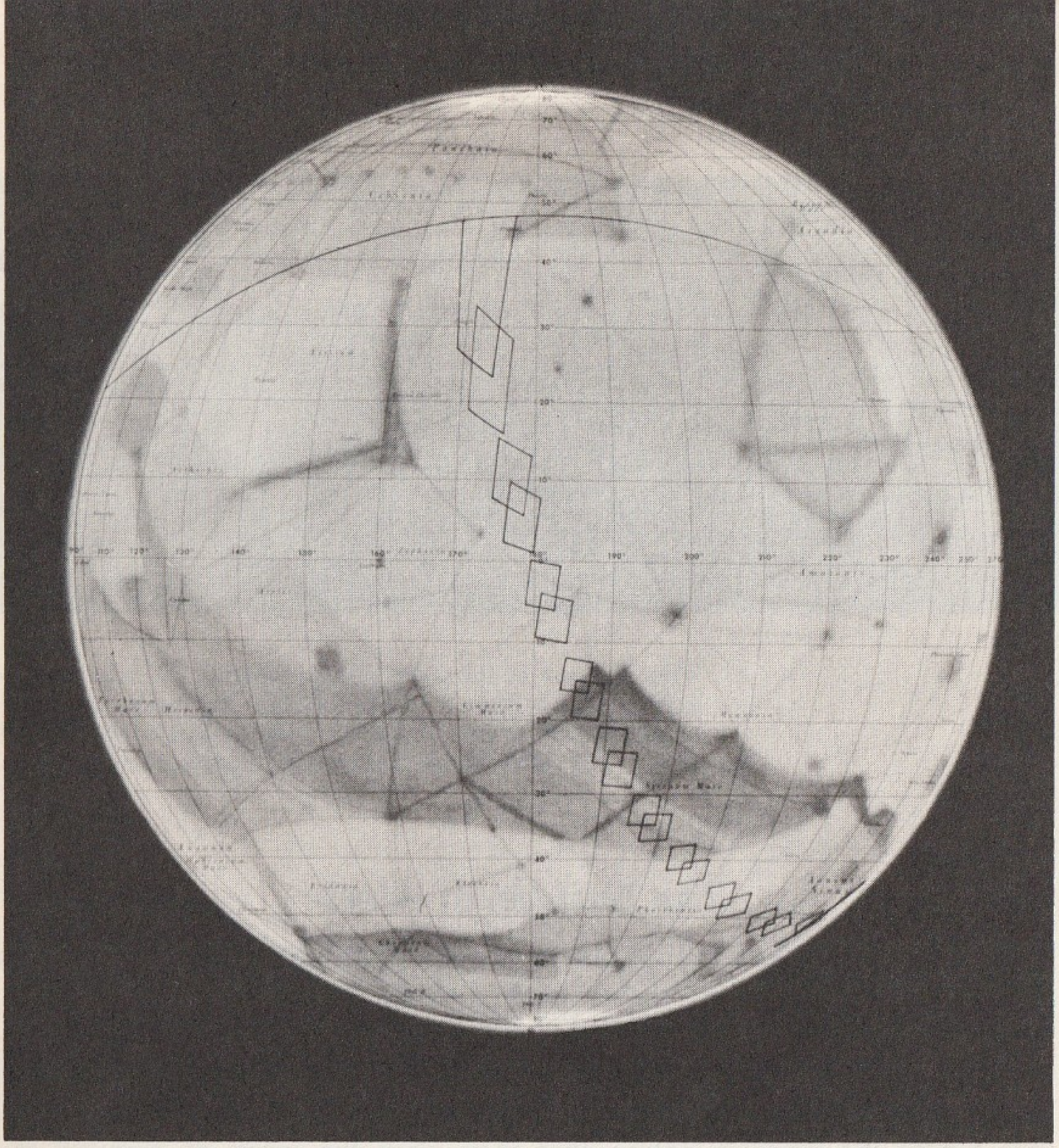
The famous "canals" on Mars are clearly visible in this painting. The Italian observer Schiaparelli named them *canali*—but they are *not* canals. The earth and moon can be seen above the Martian horizon.

from it and its orbital velocity is 13.64 miles per second. Since the orbit of Mars is much more nearly circular, it is obvious that earth and Mars approach each other most closely if the earth manages to overtake Mars when Mars is at perihelion or at least near it.

The closest Mars can come to earth is 34,797,000 miles, the farthest away it can be (when on the other side of the sun *and* in aphelion)

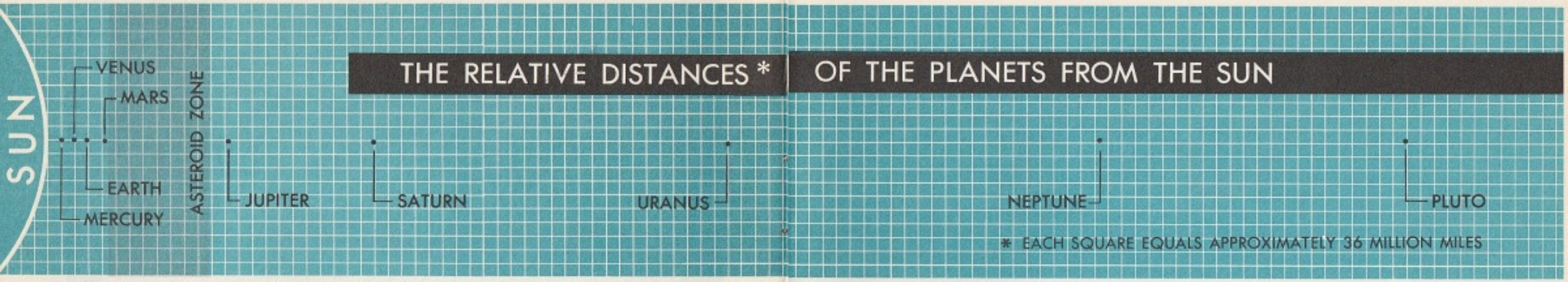
The path of Mariner IV clearly outlined against Mars; the satellite travelled to within 5,400 miles of the planet's surface. Pictures taken by a television camera from the satellite were recorded and relayed back to earth.





Pictorial representation of Mars shows areas (outlined in black) photographed in Mariner IV's historic mission in 1965.

is 340 million miles. Unfortunately these good oppositions, called *perihelion oppositions,* are fairly rare. There was a good one in 1924 and another good one in 1956. The next good one is due in 1971. We have learned enough from earlier oppositions to theorize that about three-quarters of the planet is desert and that the remaining quarter is darkish grey or green in appearance. The amount of water in the very thin Martian atmosphere is not more than five per cent of that in the earth's atmosphere, and perhaps the oxygen content is only one per cent that of earth.


THE RELATIVE DISTANCES * OF THE PLANETS FROM THE SUN
SUN
VENUS
MARS
EARTH
MERCURY
ASTEROID ZONE
JUPITER
SATURN
URANUS
NEPTUNE
PLUTO
* EACH SQUARE EQUALS APPROXIMATELY 36 MILLION MILES

This diagram of the solar system showing the relative distances of the planets from the sun has been drawn to scale. Each square equals approximately 36,000,000 miles. The planets themselves are represented by dots and their relative sizes have not been drawn to scale. It should be obvious that the sun, with a diameter of 865,000 miles, is also not drawn to scale; if it were, it would be another very small dot.

The Surface of Mars

SEVERAL FEATURES ON MARS have been interpreted as representing polar ice caps that shrink with melting in the Martian summer. There are polar caps and they do shrink in summer. Networks of fine lines on the surface of Mars were called *canali* by the Italian observer Schiaparelli; unfortunately in English the name became "canals" and this led to the popular notion that they were the work of manlike inhabitants of the planet and used for irrigation.

Temperatures on Mars are below freezing point much of the time, but the Martian equator, at noon, does warm up to about 70° F. Mars is accompanied by two small moons which have been named Phobos, meaning fear, and Deimos, terror, as befits the companions of the god of war. Because of their small size they were not discovered until 1877.

The most hotly debated question for a century has been whether there is any form of life on Mars. The fly-by of Mariner IV in July, 1965 did not settle this question nor was it intended to settle it. But Mariner IV did disclose a number of surprising results. As the spacecraft passed behind the planet, its radio signals went through the Martian atmosphere and could be used to establish the density of the atmosphere. It turned out to be only one-half of one per cent of the density of the earth's atmosphere.

The Mariner's cameras photographed large numbers of impact craters on Mars, revealing a face remarkably like our moon, at least in some areas. That was surprising to some scientists. But the fact that Mariner failed to discover a magnetic field was even more so. It eliminated a theory that once sounded reasonable. Mariner, if it proved anything, showed us how little we know about the planets in the solar system.

The Planetoids or Asteroids

THE FIRST PLANET TO BE DISCOVERED in modern times was Uranus, as you will read later. The second to be discovered was one named Ceres—and it turned out to be a very small "planet" indeed.

Its discoverer was an Italian priest, Giuseppe Piazzi, who was also professor of astronomy at Palermo. On New Year's Day 1801, Piazzi was in the midst of making some observations for the purpose of correcting an error in a star catalog that had just been published. While checking he noticed a "star" bright enough to be just visible to the naked eye, yet not recorded on star maps. This was suspicious in itself, since by that time it could be expected that any star map would record everything that was visible without instruments. Piazzi continued his observations for several weeks; then illness prevented him from making

THE MOONS OF MARS

Name	Probable diameter (miles)	Orbital period	Orbital velocity (mi./sec.)	Distance from center of Mars (miles)	Distance from surface of Mars (miles)
Phobos	10	7 hours, 39 min.	1.32	5,800	3,700
Deimos	5	30 hours, 18 min.	0.84	14,600	12,500

final calculations and conclusions. When he returned to the observatory some time later, he could find no trace of the "star". He did, however, send accounts of his findings to several astronomers in France and Germany.

One man who read of Piazzi's discovery, which Piazzi had guessed was either a comet or a new planet, was a young mathematician in Germany, Karl Friedrich Gauss. Using Piazzi's limited observations, he produced a calculation of an elliptical orbit for the new celestial body. His calculation was circulated among a number of astronomers, among them Heinrich W. M. Olbers, a well-known physician in Bremen who had his own observatory atop his house. Olbers recorded his rediscovery of the new "planet", named Ceres, exactly one year to the day after Piazzi had first seen it.

What Gauss had done was to arrive at a calculation of an orbit that placed the average distance of Ceres from the sun at 2.77 A.U. The term *A.U.* means *astronomical unit,* which is the average distance of the earth from the sun. (For some astronomical purposes, it is more practical to express distances in A.U.).

This figure of 2.77 A.U. caused a sensation among astronomers. For centuries it had been noted that there was quite a large gap between the orbits of Mars and of Jupiter. Back in 1600 Johannes Kepler stated in so many words that the solar system made no sense, mathematically speaking, unless there was an undiscovered planet between Mars and Jupiter. Some time later a German mathematician, J. D. Titius, devised a rule of thumb for the distances of the planets from the sun, which had been more or less forgotten until the German astronomer Johann Bode republished it in about 1772. Uranus, discovered in 1781, fitted this rule (it is called a rule and not a law because we don't know why it works) but the "gap" at 2.8 A.U. remained. Now Piazzi and Gauss had filled it.

The pleasure was not diminished when Olbers announced that on 28 March, 1802, he had found another "planet" in that gap. He named it Pallas. Two years later the astronomer Ludwig Harding observed Number 3 in the gap, calling it Juno. And in 1807 Dr. Olbers found

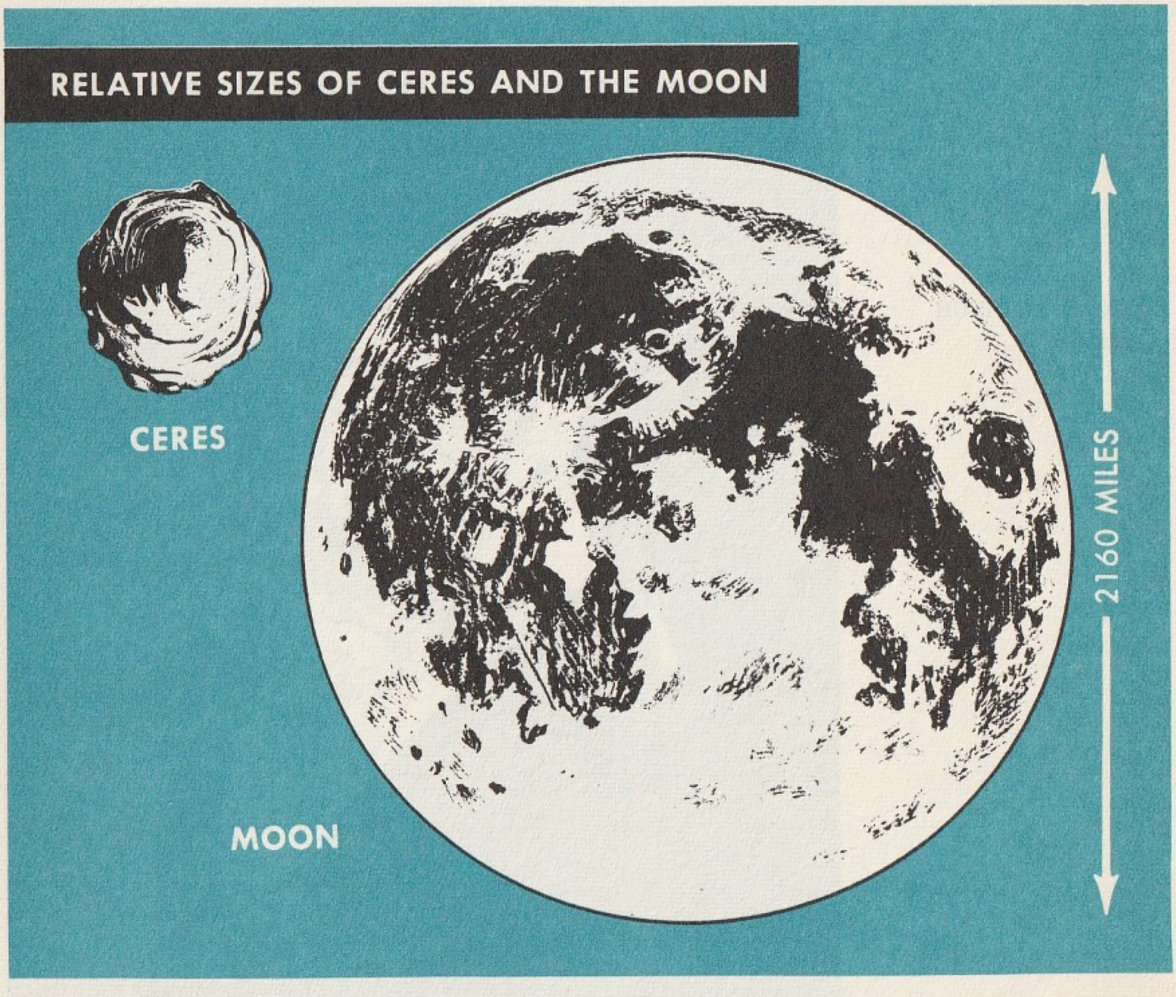
KARL FRIEDRICH GAUSS

Number 4, naming it Vesta and saying that apparently an original planet had broken into four pieces for unknown reasons.

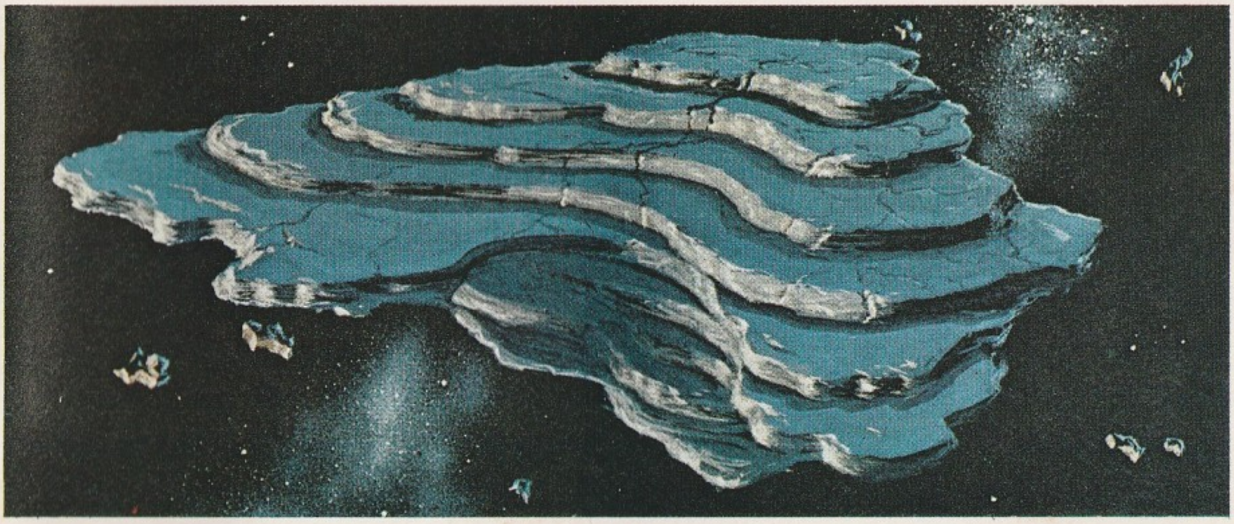
That would have been fine, but in 1845 another amateur, H. L. Hencke, announced Number 5, called Astraea, and two years later he discovered Number 6, called Hebe. Discovery has been going on ever since; by now over fifteen hundred pieces have names and astronomers believe that the total number is at least 100,000.

Naming the Planetoids

WE DON'T KNOW WHY THERE ARE 100,000 "splinters" (the largest, Ceres, is about 480 miles in diameter) in the gap instead of


RELATIVE SIZES OF CERES AND THE MOON
CERES
MOON
2160 MILES

Planetary rubble, varying in size from small lumps to objects as large as Ceres (480 miles in diameter), makes up the asteroids.



4. PLANETOIDS

One surprising fact about the asteroids, more properly called planetoids since they are not star splinters but planet splinters, is that if they were all lumped together they would form a planet smaller than Mercury.

one planet. It may be mentioned that a single planet, put together from the 100,000 pieces, would still be somewhat smaller than the planet Mercury. Total mass of all asteroids is about 1/1000 the mass of the earth. These "splinters" are called both *planetoids* and *asteroids;* the latter term is more common, the other more nearly correct.

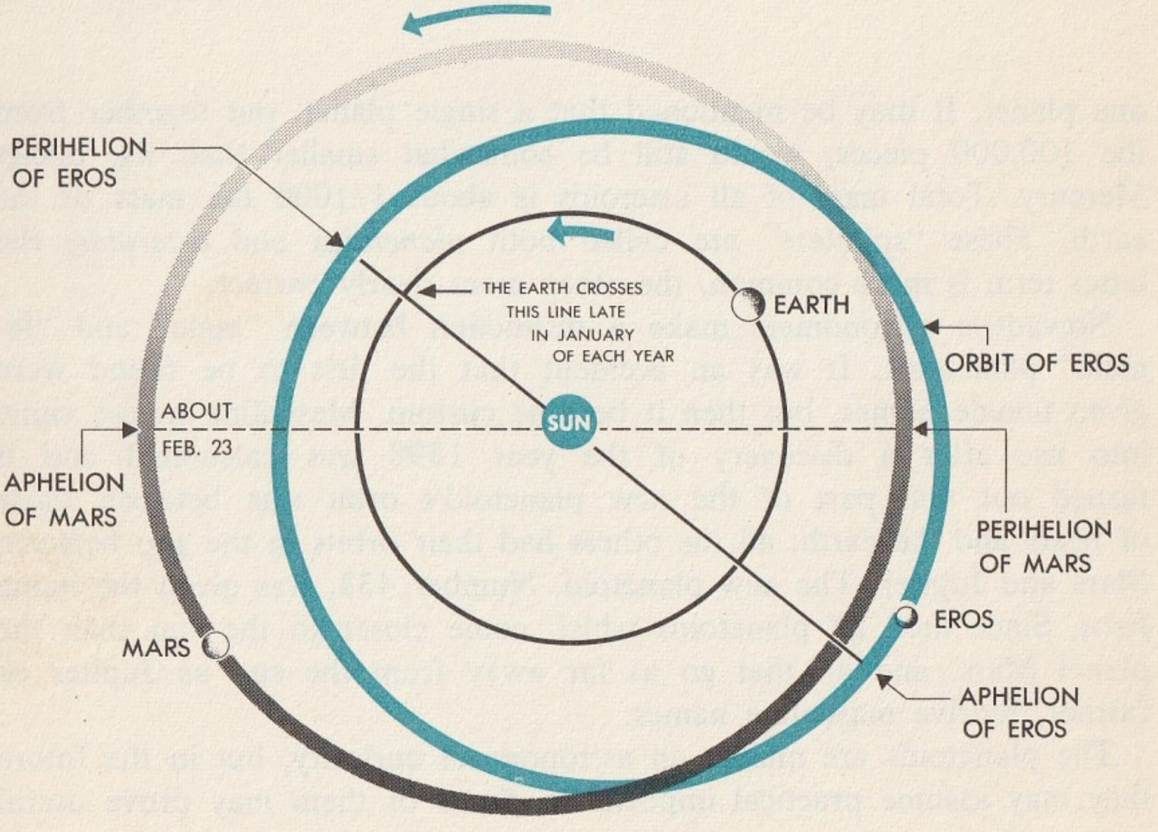
Nowadays astronomers make a distinction between "male" and "female" planetoids. It was an accident that the first to be found were given female names, but then it became custom. Masculine names came into use after a discovery of the year 1898 was calculated and it turned out that part of the new planetoid's orbit was between those of Mars and the earth; all the others had their orbits in the gap between Mars and Jupiter. The new planetoid, Number 433, was given the name Eros. Since then all planetoids which come closer to the sun than the planet Mars, and all that go as far away from the sun as Jupiter or farther, receive masculine names.

The planetoids are mainly an astronomical curiosity, but in the future they may assume practical importance. Some of them may prove useful

THE BODE-TITIUS RULE

Theoretical distance from the sun	Actual distance from the Sun	
4 + (0 x 3) : 10 = 0.4	MERCURY	0.39 A.U.
4 + (1 x 3) : 10 = 0.7	VENUS	0.72 A.U.
4 + (2 x 3) : 10 = 1.0	EARTH	1.00 A.U.
4 + (4 x 3) : 10 = 1.6	MARS	1.52 A.U.
4 + (8 x 3) : 10 = 2.8	CERES	2.77 A.U.
4 + (16 x 3) : 10 = 5.2	JUPITER	5.20 A.U.
4 + (32 x 3) : 10 = 10.0	SATURN	9.54 A.U.
4 + (64 x 3) : 10 = 19.6	URANUS	19.19 A.U.
4 + (128 x 3) : 10 = 38.8	NEPTUNE	30.07 A.U.
4 + (256 x 3) : 10 = 77.2	not matched by a known planet	

THE ORBIT OF PLANETOID NUMBER 433, EROS



Science Bulletin

Prepared by SCIENCE SERVICE

JANUS: TENTH MOON OF SATURN

The first natural satellite discovered in the solar system in many years has been found circling Saturn, and will be called Janus, after the two-faced Roman god of the doorway. Originally spotted by Dr. Audouin Dollfus of the Observatory of Physical Astronomy at Meudon, France, the discovery was later confirmed by Richard L. Walker of the U. S. Naval Observatory's Flagstaff Station.

The satellite lies very close to the edge of Saturn's rings, approximately 158,000 kilometers—or some 95,000 miles—from the planet. Its brightness is magnitude 14, too faint to be seen except through very large telescopes. This tenth satellite of Saturn circles the planet every eighteen hours, according to preliminary estimates.

Dr. Dollfus, through the Smithsonian Astrophysical Observatory in Cambridge, Mass., has asked astronomers around the world to check any photographs they took of Saturn to see if they show the satellite.

In 1610 Galileo looked at Saturn with his then newly invented telescope and saw what seemed to be only two moons, one on each side of the planet.

Saturn's rings, recently estimated to be less than one foot thick, lie exactly in the plane of Saturn's equator, which is inclined to the plane of the planet's orbit at an angle of 27 degrees. The plane of the rings keeps a fixed direction in space parallel to itself. There are two opposite positions in Saturn's orbit where the rings are edgewise to earth about once every fifteen years.

Although the ring-plane passes through the sun only once at each equinox, the earth can cross the ring-plane three times within about one year, as it did in 1966.

OBSERVATIONS OF MARS

Observations of variations in the surface level of Mars can be made from earth when conditions are favorable, Dr. D. H. Harris of the University of Arizona's Steward Observatory has found.

The ground-based observations of Martian relief are possible only when the two planets are relatively close to each other in a specific configuration and when observing conditions are near-perfect.

Previous observations made under such conditions give evidence that relief can be detected, Dr. Harris reports in the magazine "Science". The best time for observing Martian relief during the 1967 opposition was summer.

EARTH'S AGE

The earth is at least 6 billion years old, Dr. V. I. Baranov of the U.S.S.R. Academy of Sciences has concluded, after surveying the results of age determinations made on the basis of the decay of radioactive elements.

Determinations of absolute age from radioactive decay depend essentially on a comparison of the isotopes present when the object was in its original state, and at the end of the time interval being measured.

An upper limit on earth's age is given by the ratio of heavy chemical elements, such as uranium 235 and 238, and by the time required for radiogenic lead isotopes to accumulate in earth's crust.

The isotopic composition of the lead in the earth's crust limits the lifetime of terrestrial material to about five billion years, a figure substantiated by extensive experimental data. Nevertheless, Dr. Baranov's survey has shown, this limiting estimate "can by no means be considered definitely established."

Dr. Baranov believes that the 5-billion-year figure is valid only if the lead in the earth's crust has not become mixed with lead from deep within the earth that is responsible for the mean chemical composition of the earth as a whole.

Recent reports of an age for earth of more than six billion years are therefore quite possible, Dr. Baranov reported in "Soviet Astronomy", a translation of the "Astronomical Journal" of the Academy of Sciences of the U.S.S.R., published by the American Institute of Physics in New York.

EARTH'S MANTLE

The earth's mantle—the layer underlying the surface crust—may consist of a wider variety of minerals than suspected up to now, according to a report in "Science."

The report is based on a study of samples from the St. Peter and St. Paul Rocks, a series of barren islets just north of the equator in the mid-Atlantic. It has long been suspected that the rocks, which are not volcanic, are an exposure of mantle material.

Among minerals identified in a study of samples from the islets, and from dredging near them, the authors observe, are brown hornblende mylonites (highly sheared rocks), "characterized by abundant brown alkali-rich hornblende and a large and complex suite of associated minerals."

The brown hornblende mylonites were previously undescribed in reports on the rocks, they note.

The minerals, their diversity and their juxtaposition are "consistent with movement of a relatively hot (but solid) plastic rock mass through the suboceanic mantle," they report.

The report was written by William G. Nelson and Eugene Jarosewich of the U. S. National Museum and Vaughan T. Bowen and Geoffrey Thompson of the Woods Hole Oceanographic Institution.

CHEMICALS ON VENUS

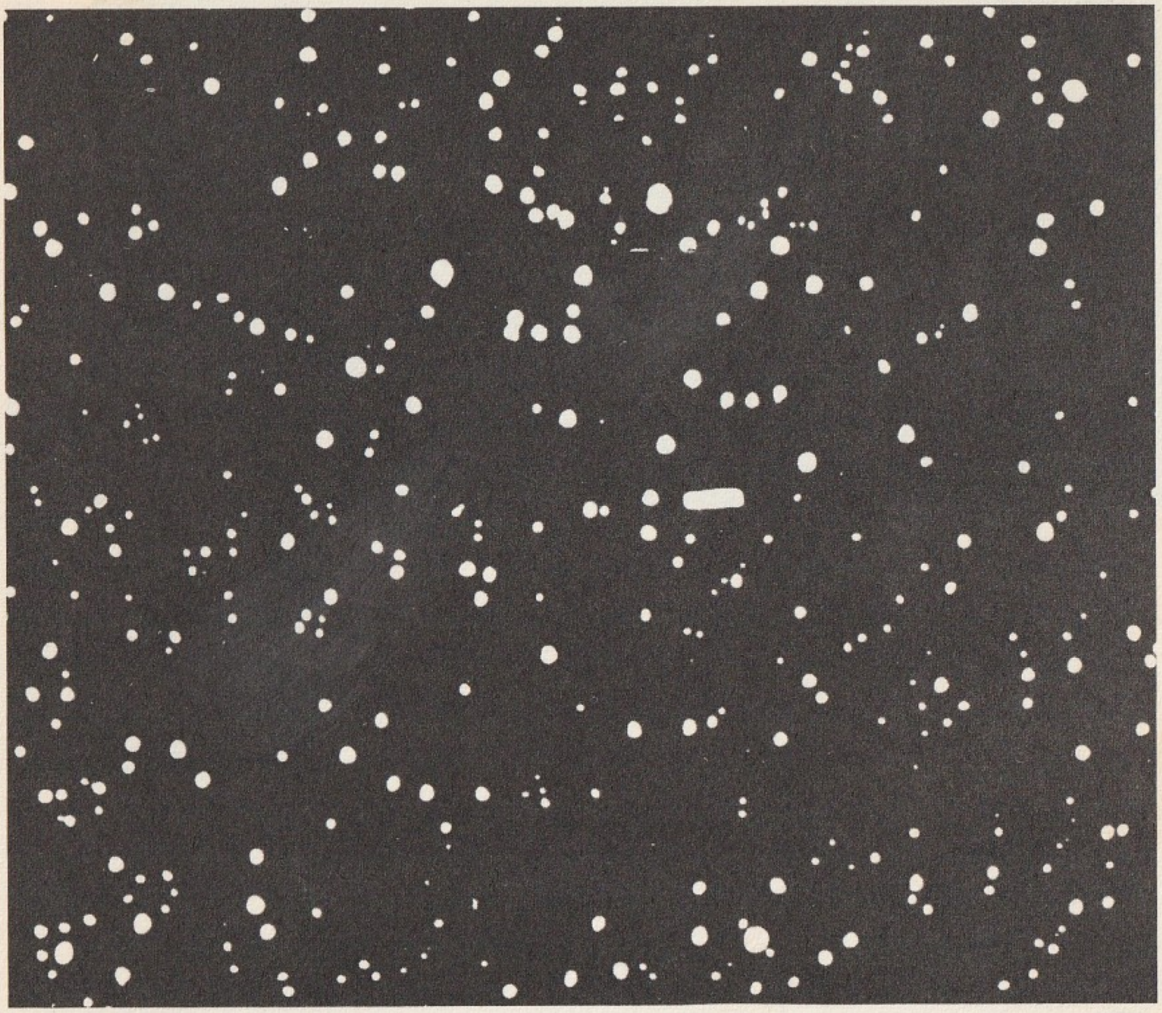
The first evidence that the atmosphere of Venus contains trace amounts of hydrogen chloride and hydrogen fluoride has been collected, using a new technique in infrared astronomy.

The observations, made in France, also confirm that carbon dioxide is the major constituent of the Venusian atmosphere.

The trace amounts of the two gaseous hydrogen halides were found with the system known as MIFS, short for multiplex interferometric Fourier spectroscopy. The technique showed that hydrogen chloride is present on Venus in less than one part per million and hydrogen fluoride has a concentration of less than a few parts per billion.

Such concentrations suggest that the acids are weak solutions in clouds of water ice, or possibly clouds of some other composition, four scientists reported in the "Astrophysical Journal".

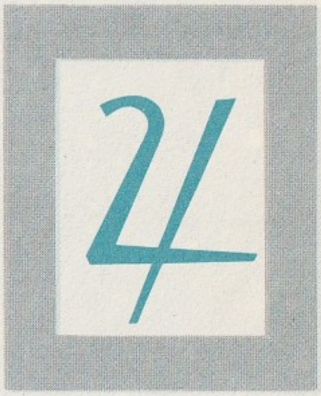
Implications of these findings concerning the surface and the atmosphere below the clouds are now being studied, according to Dr. Pierre Connes of the National Center for Scientific Research, Bellevue, France, and his three co-workers.



This is part of the photographic plate which led to the discovery of Eros.

to spaceship captains for determining the ship's position. Eros has already been used to determine the length of the astronomical unit.

Asteroids now discovered and verified number about 2,000. They could have originated from collisions of a group of smaller planets orbiting between Mars and Jupiter. Some are rough and irregular in shape, as deduced from their variations in brightness.



Symbol for Jupiter

Jupiter and Its Moons

BEYOND THE SWARM OF THE PLANETOIDS or asteroids is Jupiter, the largest planet of our solar system, moving serenely in its orbit. Though it is the largest of the planets, it has the shortest period of rotation of all of them; it turns on its axis in only nine hours, fifty minutes and thirty seconds. Because of its fast rotation Jupiter is not a sphere. One look through the telescope is enough to see how much it is flattened. Measured from one point of the equator to the opposite point of the equator, the planet's diameter is 88,700 miles; measured from pole to pole it is only 82,800 miles. Its average distance from the sun is 484 million miles.

The streaks (called belts) in Jupiter's atmosphere also indicate its quick rotation and are parallel to its equator. Embedded in these belts is a phenomenon which became famous by itself: the Great Red Spot, first noticed in 1831. It is egg-shaped and of enormous size, measuring in length about 25,000 miles and in width about 8,000 miles. The Red Spot became definitely red in about 1878 and stayed most conspicuous for about five years. Since then it has faded, but still is visible. Older drawings of Jupiter show that it existed, but was apparently not very conspicuous, for many decades before it became prominent. It was soon observed that the Red Spot lagged behind Jupiter's rotation, hence it could not be something on its surface but had to be something floating in Jupiter's atmosphere. We don't know what it is, but it could be fed

5. JUPITER

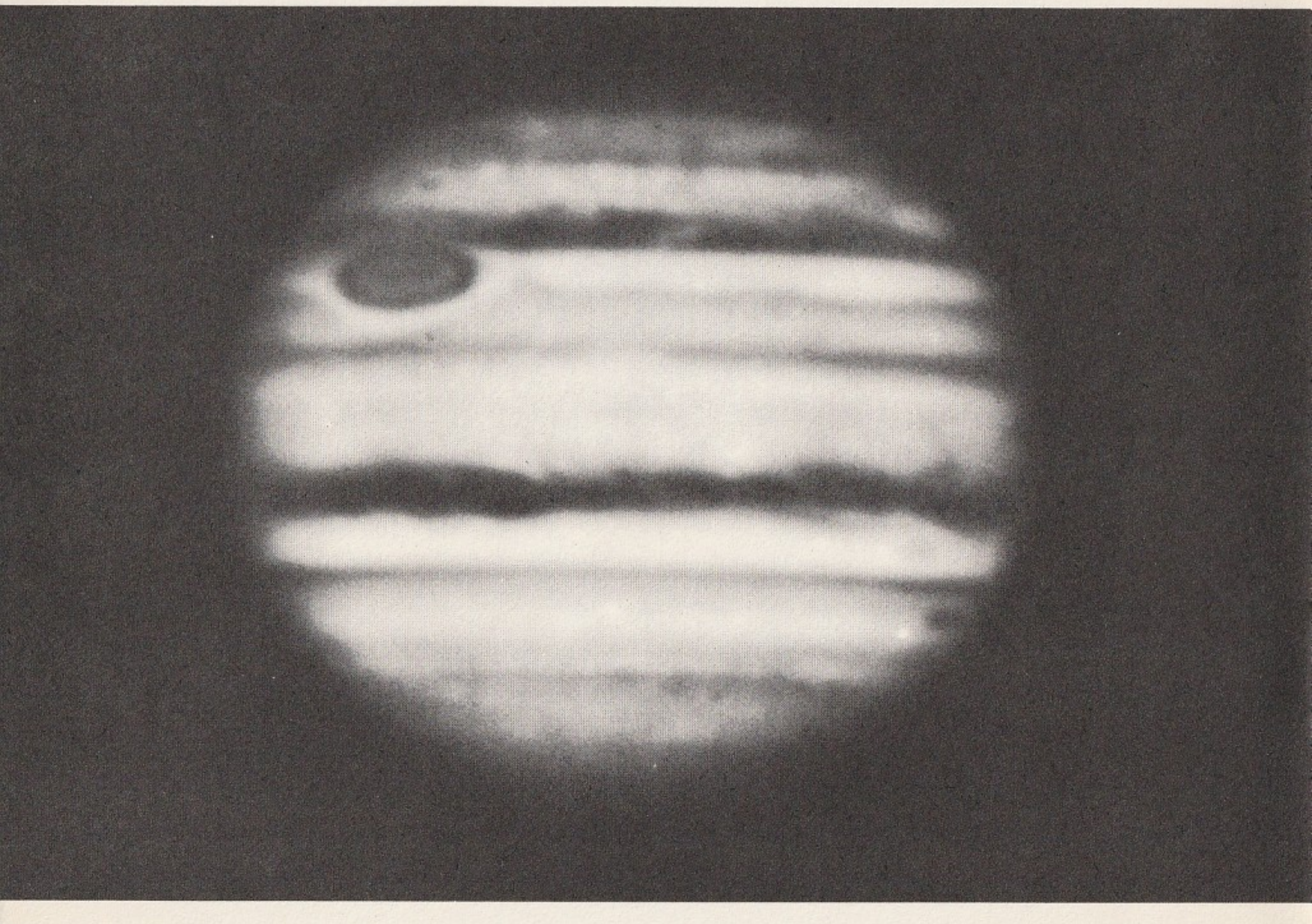
Jupiter is the largest of the planets, has the greatest number of moons, and spins rapidly on its axis, rotating once every nine hours, fifty minutes and thirty seconds. This is why its equator is 18,500 miles longer than its polar circumference. Shown here is an artist's concept.

from something on the solid surface of the planet. Temperature on Jupiter is about minus 200° F.

The four outer planets, of which Jupiter is the largest, differ from the four inner planets not only in size but in every respect. The inner planets are relatively small solid bodies. The outer planets consist mostly of gas, almost all of it hydrogen. In fact they are often called the "gas giants". In the upper layers of Jupiter's atmosphere other gases, such as ammonia and methane (so-called marsh gas), have been detected, and helium is believed also to be present. Some scientists believe Jupiter supports life.

If Jupiter has a solid core (and what is said here about Jupiter also applies to the three other gas giants: Saturn, Uranus and Neptune), the

This photograph of Jupiter was taken by the 200-inch Hale telescope at Mount Palomar using blue light. Note the Red Spot in its atmosphere.



THE SATELLITES OF JUPITER

Name	Year of discovery	Mean distance from planet (miles)	Orbital period (days)	Diameter (miles)
J-V (Amalthea)	1892	112,600	0.50	100
J-I Io	1610	261,800	1.77	2,300
J-II Europa	1610	416,600	3.55	2,000
J-III Ganymede	1610	664,200	7.15	3,200
J-IV Callisto	1610	1,169,000	16.69	3,200
J-VI	1904	7,114,000	250	100
J-VII	1905	7,292,000	260	40
J-X	1938	7,350,000	260	15
J-XII	1951	13,000,000	625	15
J-XI	1938	14,000,000	700	15
J-VIII	1908	14,600,000	739	40
J-IX	1914	14,700,000	758	20

core must be quite small. Radio noise from Jupiter suggests the planet has a hot solid core beneath the clouds which would necessitate a drastic revision of earlier ideas of Jupiter's icy structure.

A Dozen Moons

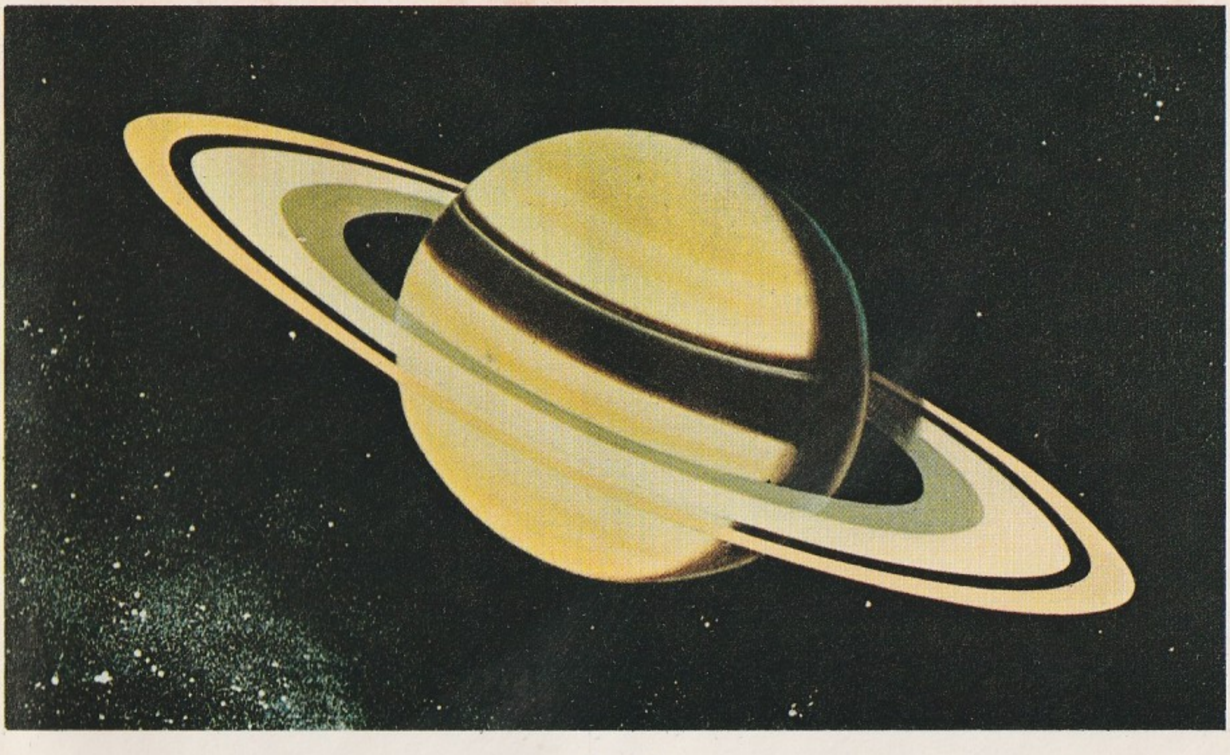
THOUGH JUPITER GETS LITTLE LIGHT or heat from the sun, its atmosphere seems to be in steady and violent motion. It is quite certain that no spaceship will dare to enter Jupiter's atmosphere, but one day an observation station could be set up on one of its moons.

Jupiter has the largest number of known moons of all the planets. At the moment twelve of them are known. Four of them are very large, two about the size of Mercury and the two others about the size of our own moon. These four were discovered by Galileo Galilei in 1610 with the first primitive astronomical telescope and can be seen through any good binoculars.

In 1892 the American astronomer Edward Barnard found a fifth moon of Jupiter, small (about 100 miles in diameter) and closer to the planet than the four large ones.

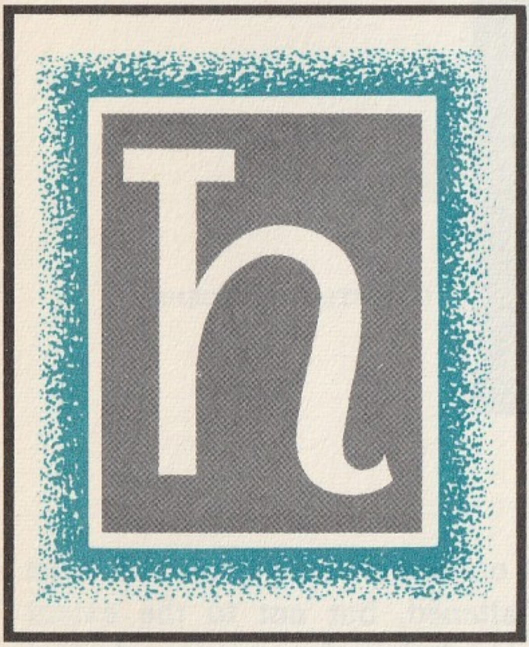
The other seven moons were discovered gradually between 1904 and 1951. They move around their planet in oddly assorted orbits, three at distances about 7 million miles from the planet and four others at distances about 14 million miles. Four of them (Numbers VIII, IX, XI and XII) are what astronomers call retrograde. Normally moons move around their planets in the same direction in which planets move around the sun, counterclockwise when seen from the North or from "above" the solar system. These four move clockwise.

Satellites of Jupiter were used in experiments in 1675 to demonstrate the finite velocity of light. The inner two satellites are believed to be covered by a layer of ice or hoarfrost.



6. SATURN

Saturn, with its unique system of rings, is visible to the naked eye. It is comparable to the brighter stars. The rings are probably not more than ten miles thick but extend (from inside to outside) for over 40,000 miles.



Symbol for Saturn

Saturn, Its Rings and Moons

Unless there is a large and bright comet in the sky, the most beautiful and interesting celestial body to be seen is Saturn and its rings. Of course, a telescope is needed (a small one will do) to see the rings. Saturn is nearly twice as far from the sun as Jupiter and only slightly smaller. It is the second of the gas giants, both in the order of distance from the sun and in size. It probably resembles Jupiter greatly in composition but in the deep hydrogen atmosphere of Saturn things appear to be much quieter than on Jupiter.

Christian Huygens

Like all the gas giants Saturn rotates fast on its axis (ten hours, fourteen minutes) and its disk looks oblate or flattened, but not to the extent that Jupiter's disk does. Saturn has cloud bands but they are less distinct than Jupiter's. Its temperature is minus 250° F.

Saturn has nine moons—some scientists say that with a reported discovery in 1967 the number is ten. The largest is Titan, which is roughly the same size as the planet Mercury—3,100 miles in diameter. Titan is the only moon in the solar system large enough to have an atmosphere. The atmosphere of Titan is known to contain methane and probably ammonia, hence the atmosphere of Titan is the same as the atmosphere of the large outer planets. Of the other moons, Iapetus is interesting because one of its hemispheres is about five times as bright as the other, where there must be a large darkish area. We know neither what it is nor why it is there.

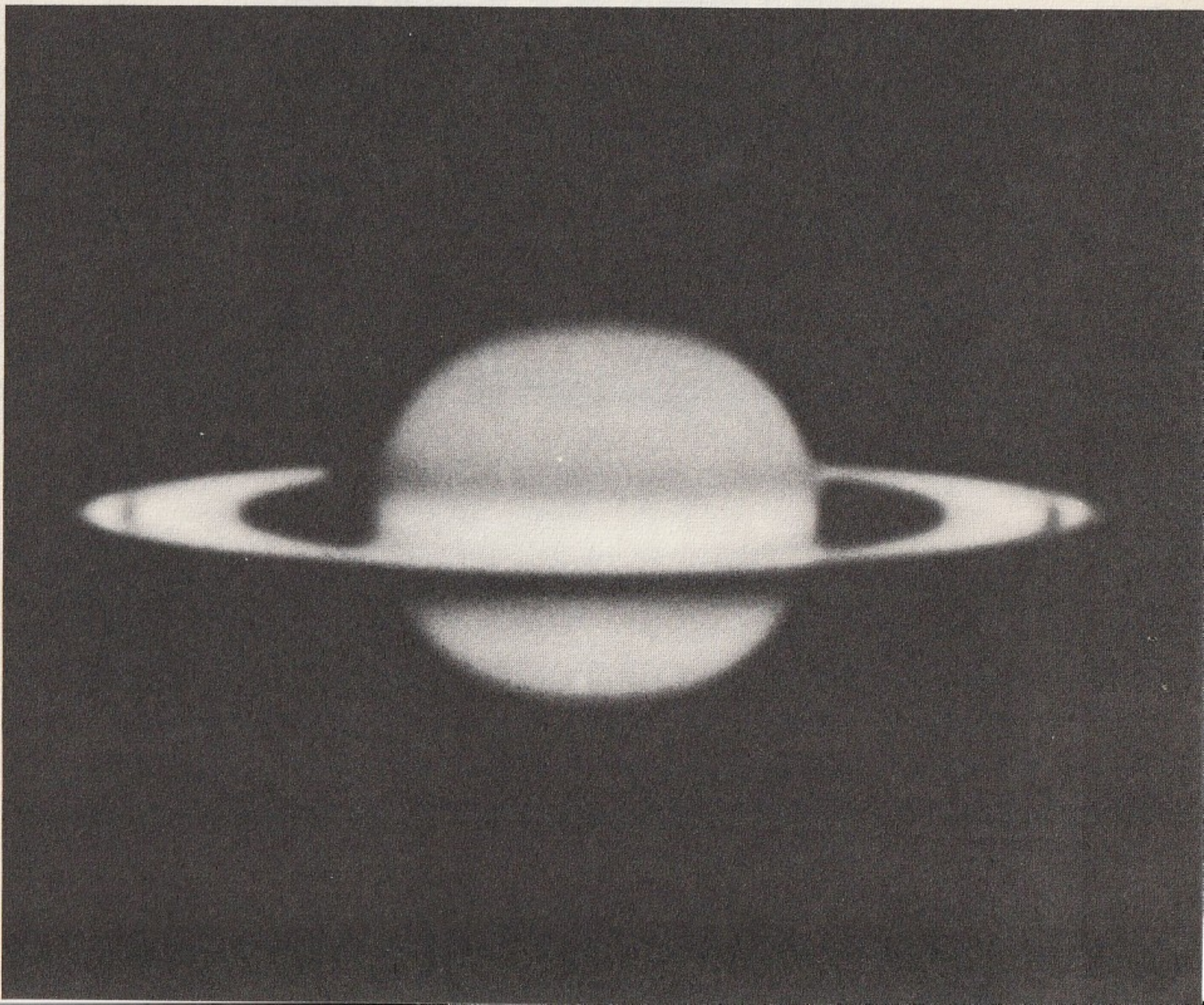
Unlike the moons of Jupiter, which have wildly tilted orbits, those of Saturn move in very nearly the same plane, except the outermost one, little Phoebe, which is retrograde.

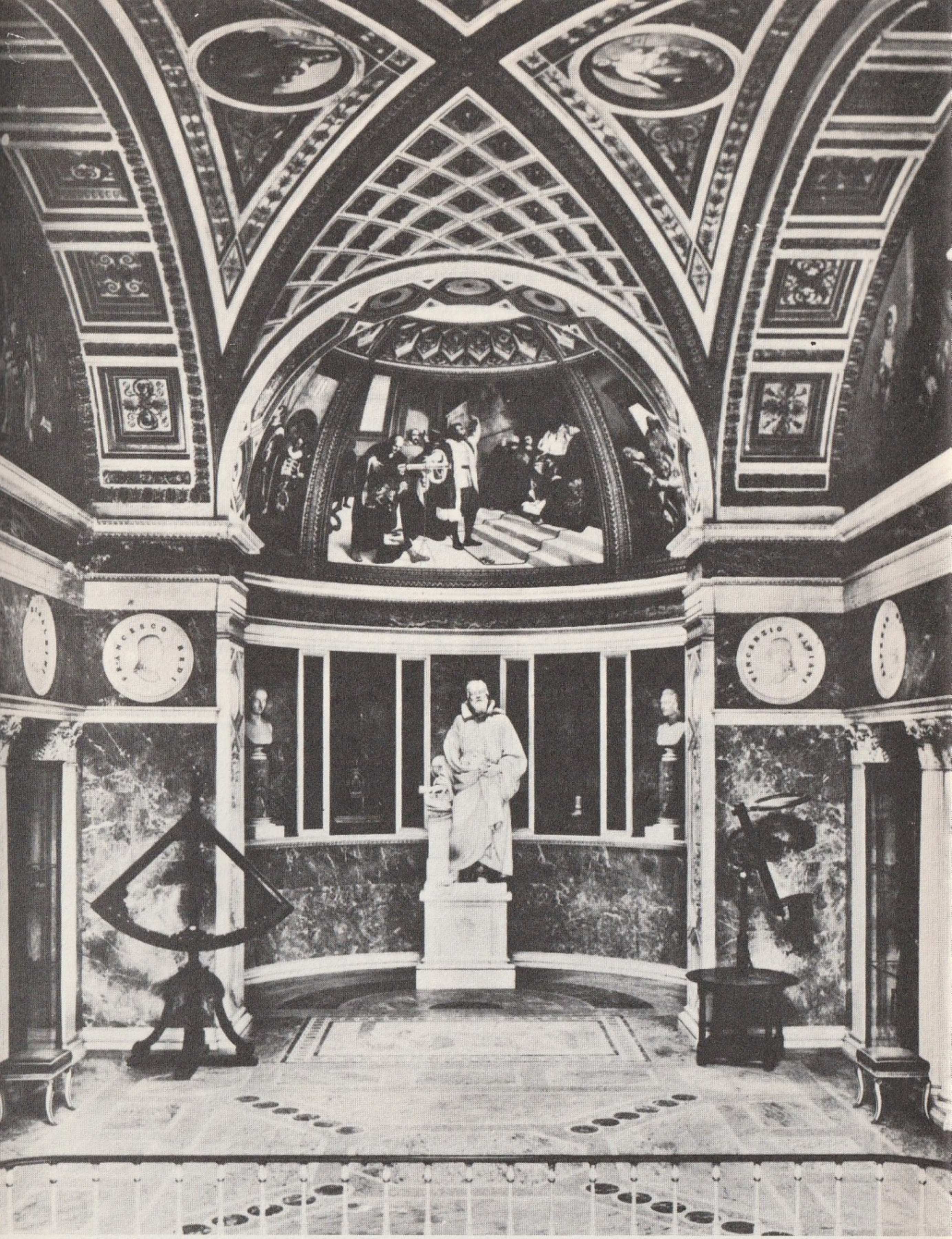
Discovery of the Rings

THE RINGS OF SATURN, it has been established by careful measurements, are actually somewhat brighter than the planet itself. The man to see them first, Galileo Galilei, was puzzled by them. His telescope was not good enough to show what they actually were—besides, nobody had ever heard of rings around a planet—and they looked to him like two very large satellites which never changed position.

It was Christian Huygens who established beyond doubt that the mysterious objects were rings which did not touch the planet anywhere. To be precise, Huygens reported "a ring"; that there are more than one was found by the Italian-born French astronomer Jean Dominique Cassini (who also discovered the moons Tethys, Dione, Rhea and Iapetus). He saw that there was a dark dividing line which, to this day, is known as *Cassini's division*. It is now customary to talk of three rings, the

Every fifteen years we see the rings of Saturn edge on, and they appear as thin needles of light standing out from Saturn's equator. This photograph was made by the 200-inch Hale telescope at Mount Palomar.





The Tribune of Galileo in the Museum of Natural History in Florence, Italy.

THE SATELLITES OF SATURN

Name	Year of discovery	Mean distance from planet (miles)	Orbital period (days)	Approx. diameter (miles)
Mimas	1789	115,000	0.94	370
Enceladus	1789	148,000	1.36	460
Tethys	1684	183,000	1.89	750
Dione	1684	234,000	2.74	900
Rhea	1672	327,000	4.52	1,500
Titan	1655	759,000	15.94	3,100
Hyperion	1848	920,000	21.28	300
Iapetus	1671	2,210,000	79.33	1,000
Phoebe	1898	8,034,000	550	200
[**Unnamed**]*	1967	52,000	.75	100-200

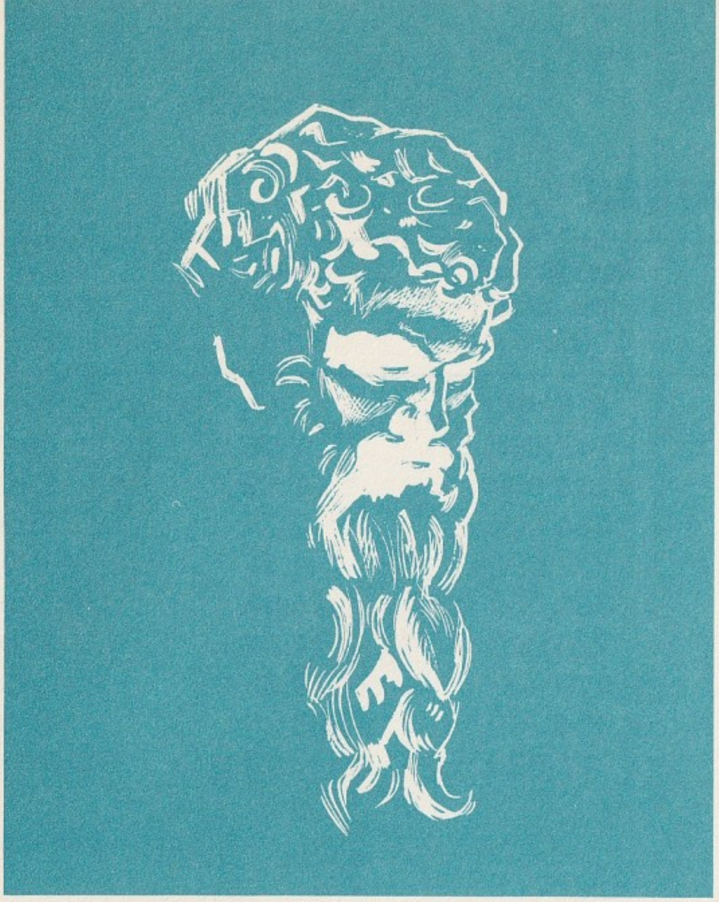
*Tentative finding

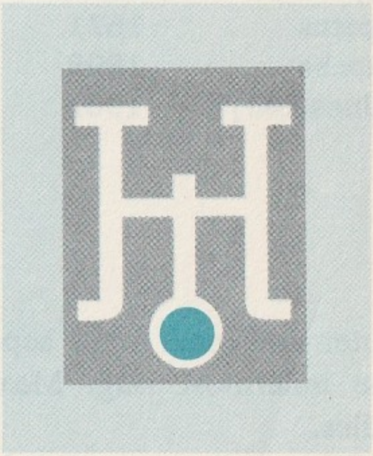
outer and inner rings separated by Cassini's division, and the *crape ring,* the innermost ring. Maximum diameter of the outer ring is 170,000 miles.

Though large and bright, the rings are very thin—perhaps a foot thick. When we see them edge on, which happens every fifteen years, they simply disappear.

The shadow cast by the rings on the planet looks quite black. The rings consist of particles or chunks rotating around the planet. It is now fairly certain that most of these particles which form Saturn's rings are ice crystals, probably interspersed with small solid particles. Because the rings are so thin, their total mass is not large. If they came together to form a ball, it would weigh only about one per cent of the weight of our moon. And our moon is only one-eightieth of the weight of our earth.

How were the rings formed? According to Dr. J. Allen Hynek of the Dearborn Observatory, a host of tiny moonlets evidently solidified about Saturn as the planet itself was condensing. Under the powerful force of the planet's gravity, the moonlets could not form into a moon that close to Saturn and they broke up and formed the rings instead. Other pieces of matter further out did form, however, and that accounts for the moons that orbit Saturn.





Symbol for Uranus

Uranus, the First "Modern" Planet

Uranus, the planet beyond Saturn, was the first to be discovered since classical times. The ancients had known Mercury and Venus, and Mars and Jupiter and Saturn, since all of them were bright enough to be visible with the naked eye and were conspicuous because of their movement among the stars. Uranus cannot be seen without a telescope, hence its discovery had to wait until optical instruments were perfected.

The man who discovered Uranus was Sir William Herschel in England. In the evening hours of Tuesday, 13 March, 1781, Sir William examined a number of small stars in the constellation Gemini, and, as he reported later: "I perceived one which was visibly larger than the rest; being struck with its uncommon magnitude I compared it with H Geminorum . . . finding it to be much larger [I] suspected it to be a comet." It took several months of observation to show that the new body was a planet; being so far distant from the sun it moved very slowly. Later it was learned that Uranus had been seen earlier by other astronomers, all of whom had thought that it was a star which had not yet been entered into the star maps. Uranus was first entered on a map in 1690.

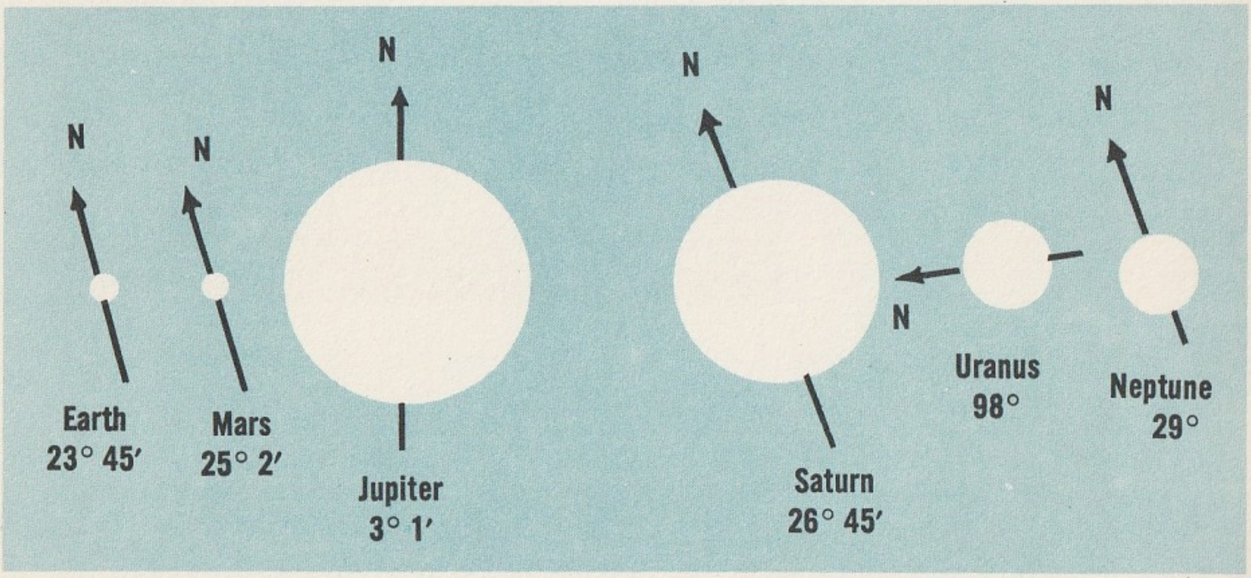
Like Jupiter and Saturn and like the planet Neptune beyond it, Uranus

7. URANUS

The planet Uranus as depicted from its nearest moon, Miranda. Vast though it is, Uranus rotates in less than eleven hours; and because its axis is inclined from the vertical by 98° the sun shines on each pole for about twenty years.

is one of the gas giants. Much larger than the earth, 29,500 miles in diameter, it is 1.8 billion miles from the sun and is greenish in hue. It revolves about the sun in eighty-four years. Uranus is mainly interesting for a reason that few people would have suspected. Observers tried early to establish its period of rotation. But the observations simply made no sense until it finally turned out that the axis of Uranus is weirdly tilted. The axis of Jupiter is nearly upright on its orbit; it is inclined from the vertical by only 3°1′. The axis of earth deviates from the vertical by 23°45′, but that of Uranus is tilted by 98°. In other words the axis of Uranus almost coincides with the plane of its orbit. Though Uranus rotates on its axis in ten hours, forty-nine minutes, the sun will shine on its North Pole for some twenty years, then slowly move around over the planet's equator and then stay over the planet's South Pole area for another twenty years or so.

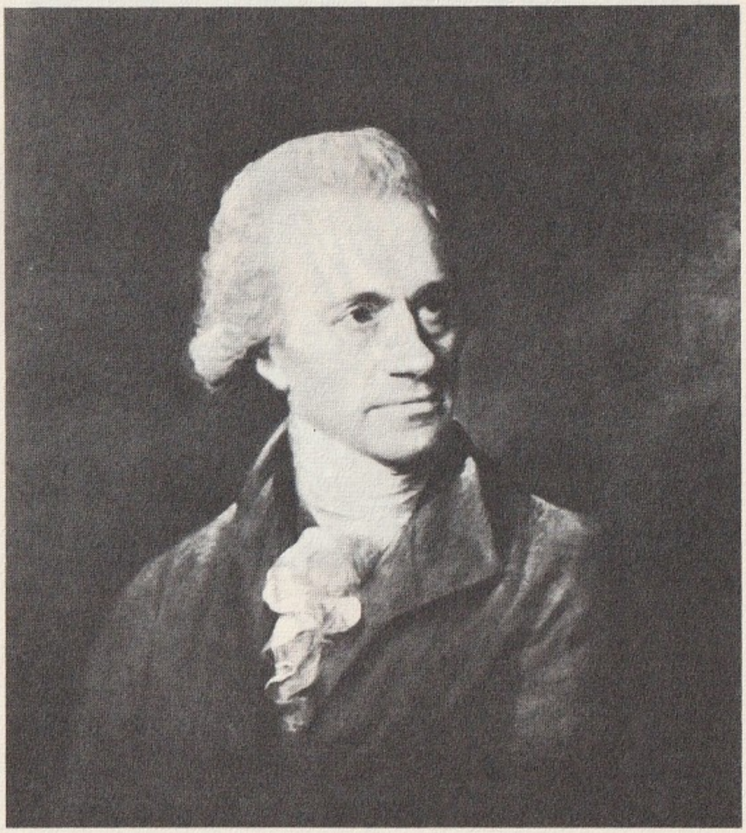
If the planet were nearer the sun, the angle of its axis would cause an almost impossibly strange climate, but seen from Uranus the sun is only a very brilliant star which hardly influences the local "weather". The planet's temperature is minus 300° F.



A major puzzle still unanswered with regard to Uranus is why, while the equatorial inclination of other planets is similar to earth's, Uranus's is about 98°.

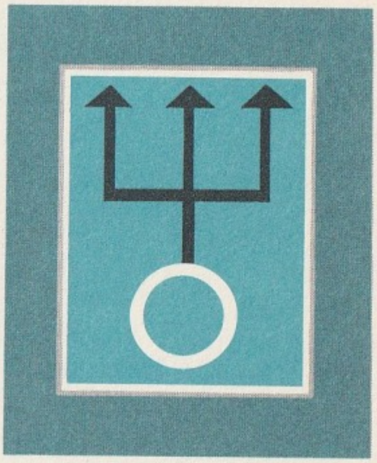
THE MOONS OF URANUS

	Mean distance from planet (miles)	Orbital period (days)	Probable diameter (miles)
Miranda	80,800	1.41	150(?)
Ariel	119,100	2.52	500
Umbriel	165,900	4.14	500
Titania	272,000	8.71	1000
Oberon	364,000	13.46	1000



SIR WILLIAM HERSCHEL

Uranus is accompanied by four large moons and one small one. Sir William Herschel himself discovered two of them in 1787 and named them Titania and Oberon (each is about 1,000 miles in diameter). The English astronomer William Lassell discovered two others in 1851 and named them Ariel and Umbriel (these are about 500 miles in diameter) and, in 1948, Gerard P. Kuiper found a fifth moon of Uranus, only about 150 miles in diameter, which he named Miranda.



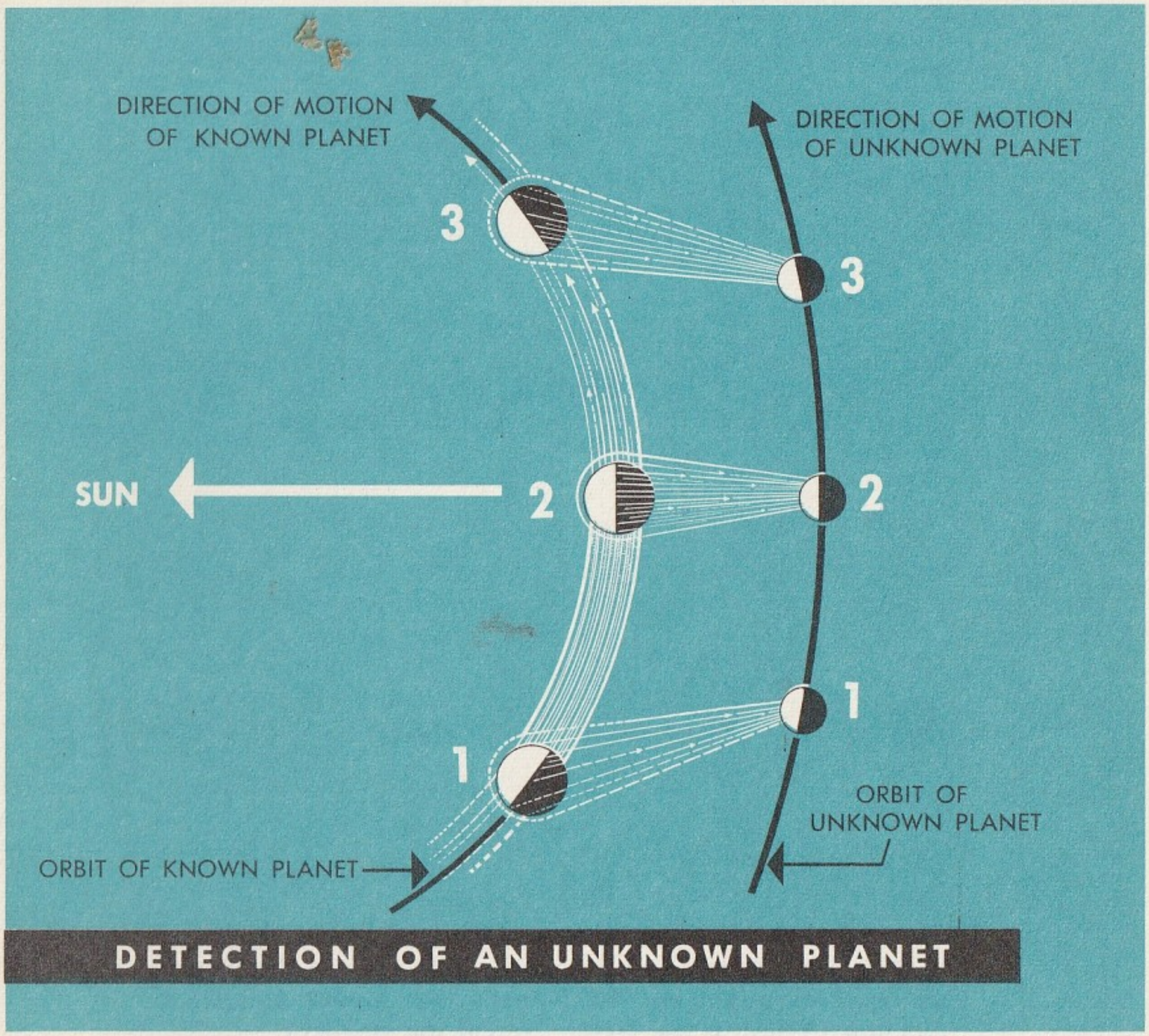
Symbol for Neptune

Neptune, Discovered to Order

URANUS, LIKE CERES, the first of the planetoids to become known, was discovered accidentally. But the existence of the planet Neptune was predicted. It was found by the German astronomer Johann Gottfried Galle, on 23 September, 1846, because the French astronomer Urbain J. J. Leverrier had told him where to look for an unknown planet.

Leverrier had calculated that there had to be such a planet and where it should be in the sky if it could be seen at all with a good telescope. Later it became known that the English astronomer John C. Adams had made the same calculations at about the same time as Leverrier, but the astronomical observer whom he had requested to find the planet had been negligent.

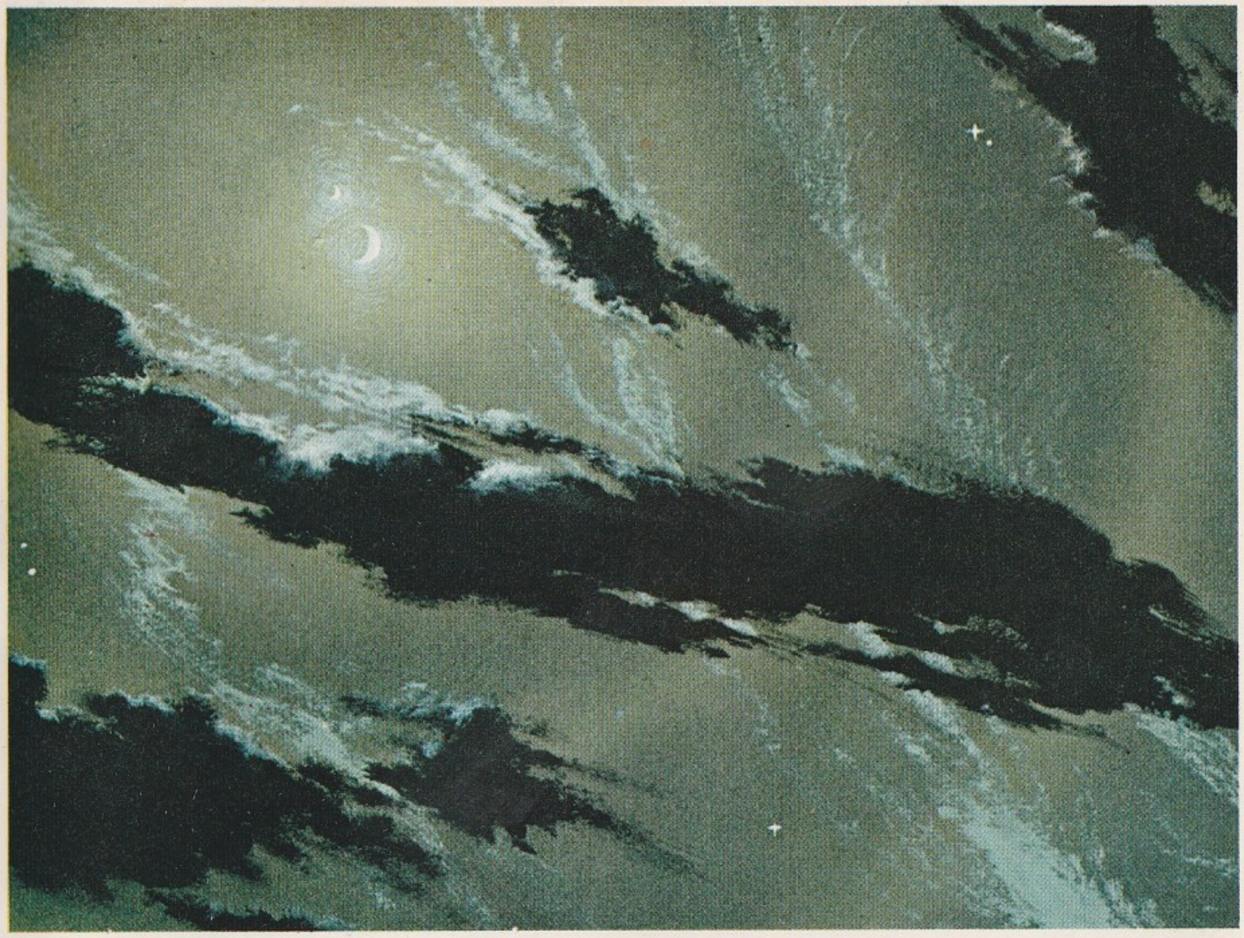
How could Leverrier and Adams find that there was an unknown planet by calculating? The actual calculations are too involved to be discussed here but the principle can be explained. Let us assume that only two planets are going around the sun—the inner one is known and the outer one is not. If both planets are located at the position *1,*


DIRECTION OF MOTION OF KNOWN PLANET
DIRECTION OF MOTION OF UNKNOWN PLANET
3
3
SUN
2
2
1
1
ORBIT OF UNKNOWN PLANET
ORBIT OF KNOWN PLANET

DETECTION OF AN UNKNOWN PLANET

the unknown planet is somewhat "ahead". Now the two planets attract each other. The result, in this position, is that the outer planet is slowed down a little and the inner one is speeded up a little; it moves faster than it would if the other planet were not there.

Of course, we don't know about the outer planet yet; all we see is that the inner planet moves a little faster than it should. As the inner

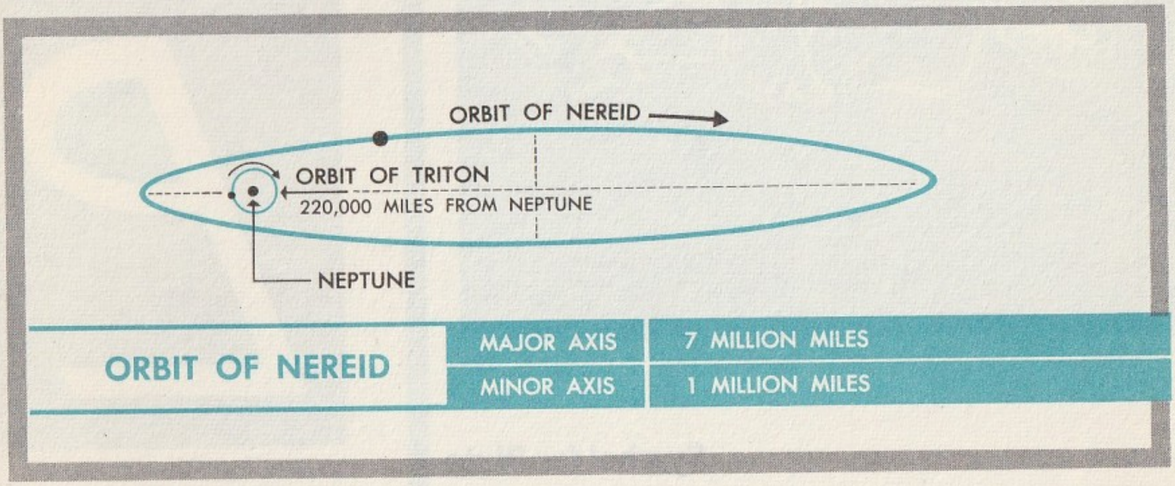


8. NEPTUNE

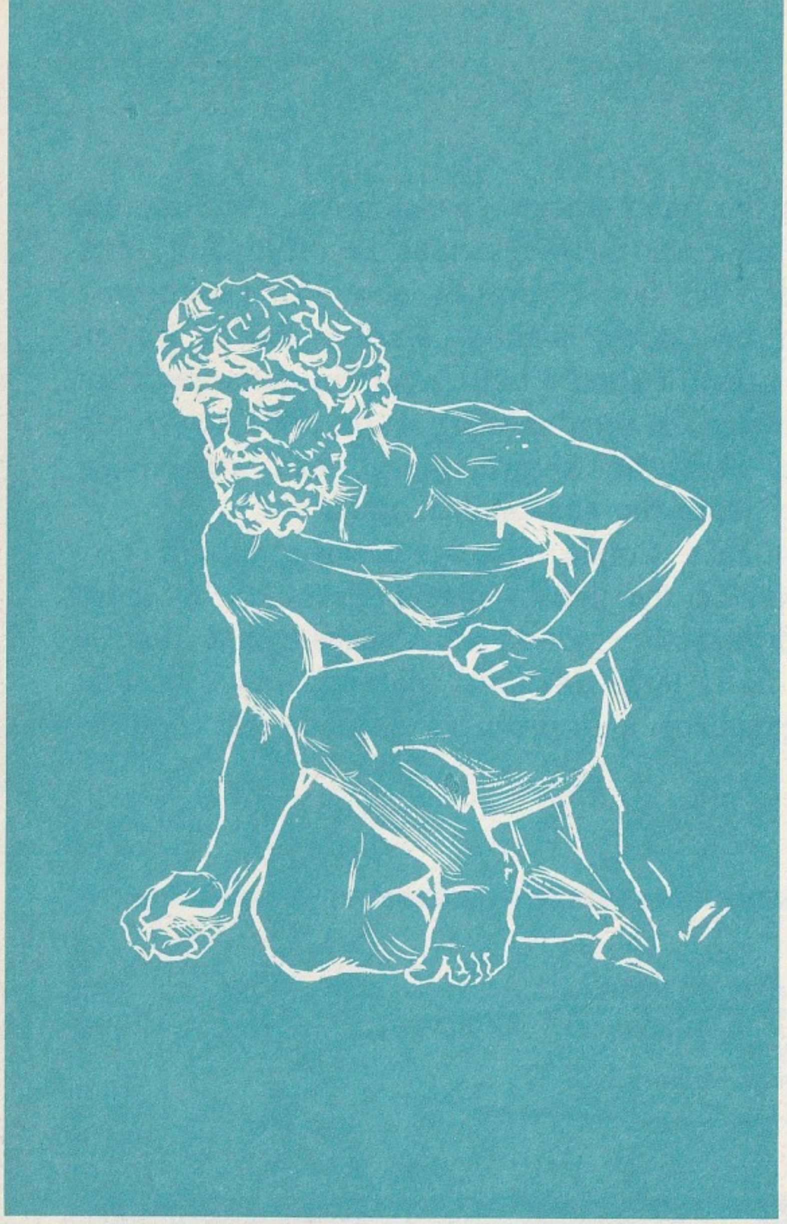
The sky above Neptune is always covered by clouds, but if there were a break in the cloud cover, this is the way an observer might see the planet's two moons at *conjunction* (Triton is the larger, Nereid the smaller).

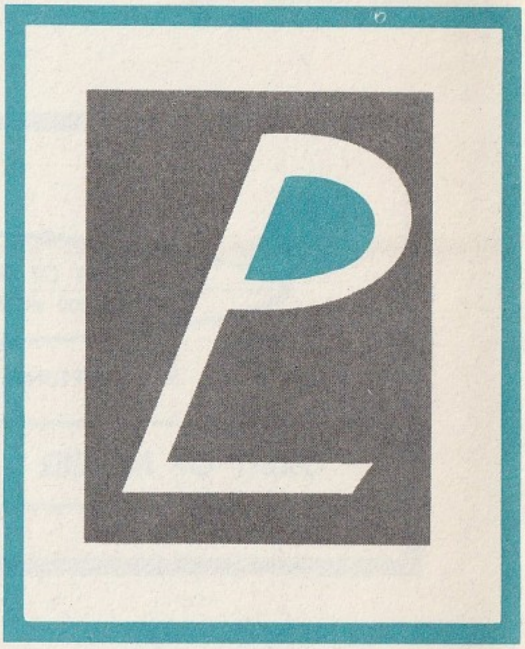
planet, moving faster, passes the outer planet (position 2), their mutual gravitational pull does not influence their velocities in orbit. But after they have passed each other, the forces reverse; now the (unknown) outer planet slows the inner one down slightly. Finding that a known planet moves somewhat faster than it should until a certain date, and then finding out that the same planet is then moving a bit too slowly, an astronomer would conclude that the known planet had passed an unknown planet farther away from the sun on that date.

The actual case was not that simple (partly because Saturn and Jupiter also exerted some pull on the known planet Uranus), but both Leverrier and Adams found that the motion of Uranus could not be explained unless there was a fairly large unknown planet in space beyond Uranus. That is how the existence and probable position of Neptune was calculated.



As expected, Neptune turned out to be one more large planet, with a diameter of 26,800 miles at a distance of 2.8 billion miles from the sun. It takes 165 years to circle the sun. Like Jupiter, Saturn and Uranus, it is covered by an atmosphere of hydrogen, methane and ammonia. Like Uranus it is greenish in hue. Its large moon Triton (which has a diameter of 3,000 miles, almost as large as Mercury) was found in the same year as the planet itself. Much later, in 1949, a second moon of Neptune was found which is quite small (diameter about 200 miles) and has a very unusual orbit. It is quite possible that Neptune has other small moons which we cannot see because of the great distance.

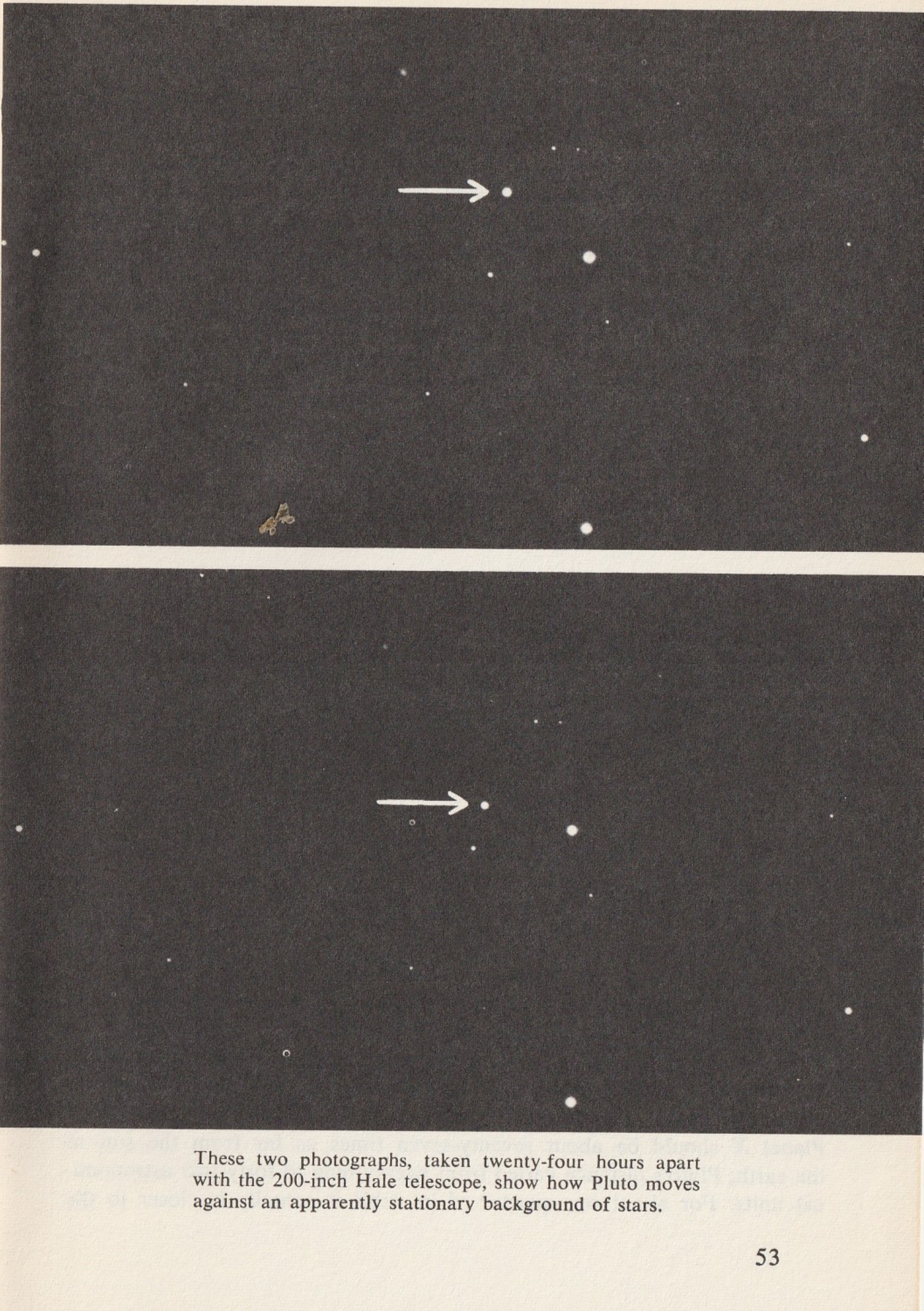




Symbol for Pluto

Pluto and Planet X

IT WAS ONLY NATURAL, after the discovery of Neptune by mathematics, that scientists wondered whether the orbit of Neptune would also show irregularities which might lead to the discovery of still another planet beyond Neptune. Since the letter *X* is employed in mathematics to denote an unknown, the possible planet beyond Neptune was called Planet *X*.

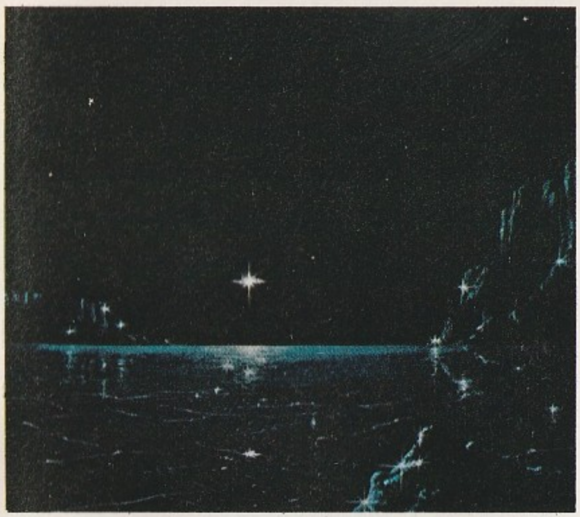


These two photographs, taken twenty-four hours apart with the 200-inch Hale telescope, show how Pluto moves against an apparently stationary background of stars.

Since Neptune needs nearly 165 years to go around the sun once, everybody knew that at least fifty years of observation would be needed before the position of a more distant planet could be determined. The existence of Planet *X* was suspected because the existence of Neptune did not account *fully* for the irregularities in the motion of Uranus.

By about 1900 several astronomers, especially the American Percival Lowell, felt certain that there were such indications and the search was on. In January, 1930 Clyde Tombaugh completed the search: Planet *X* had been discovered. It was named Pluto, the letters PL being in honor of Percival Lowell.

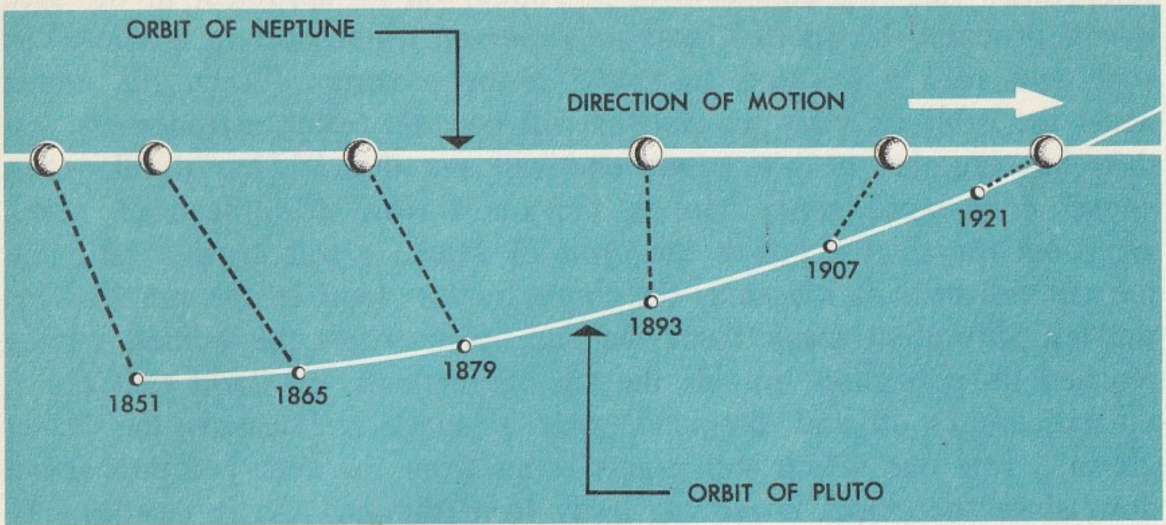
Looking towards the sun from the outermost of the planets, Pluto. It has been suggested that Pluto began as a moon of Neptune.



9. PLUTO

While there was no doubt that Tombaugh had discovered a new planet, astronomers soon had many reasons to wonder whether Pluto was actually the Planet *X* they had been looking for. To begin with, Pluto was not a gas giant but seemed to be slightly smaller than earth. Its orbit is very strongly inclined to the plane of the ecliptic. Most important, it was far too near the sun. According to the Bode-Titius rule, Planet *X* should be about seventy-seven times as far from the sun as the earth; Pluto's distance varied from twenty-nine to forty-two astronomical units. For about one-quarter of its orbit it actually is closer to the

THE RELATIVE POSITIONS OF NEPTUNE AND PLUTO AS SEEN FROM THE SUN FOR ABOUT 80 YEARS PRIOR TO PLUTO'S DISCOVERY.



Owing to Pluto's very elongated orbit, it is more than fifty astronomical units at aphelion and within 30 A.U. at perihelion. Since Neptune's mean distance from the sun is more than 30 A.U., this means that the planets pass each other. There is no possible chance of collision between the two planets because of the differing inclinations of their orbits. The nearest approach of Pluto and Neptune is 240 million miles.

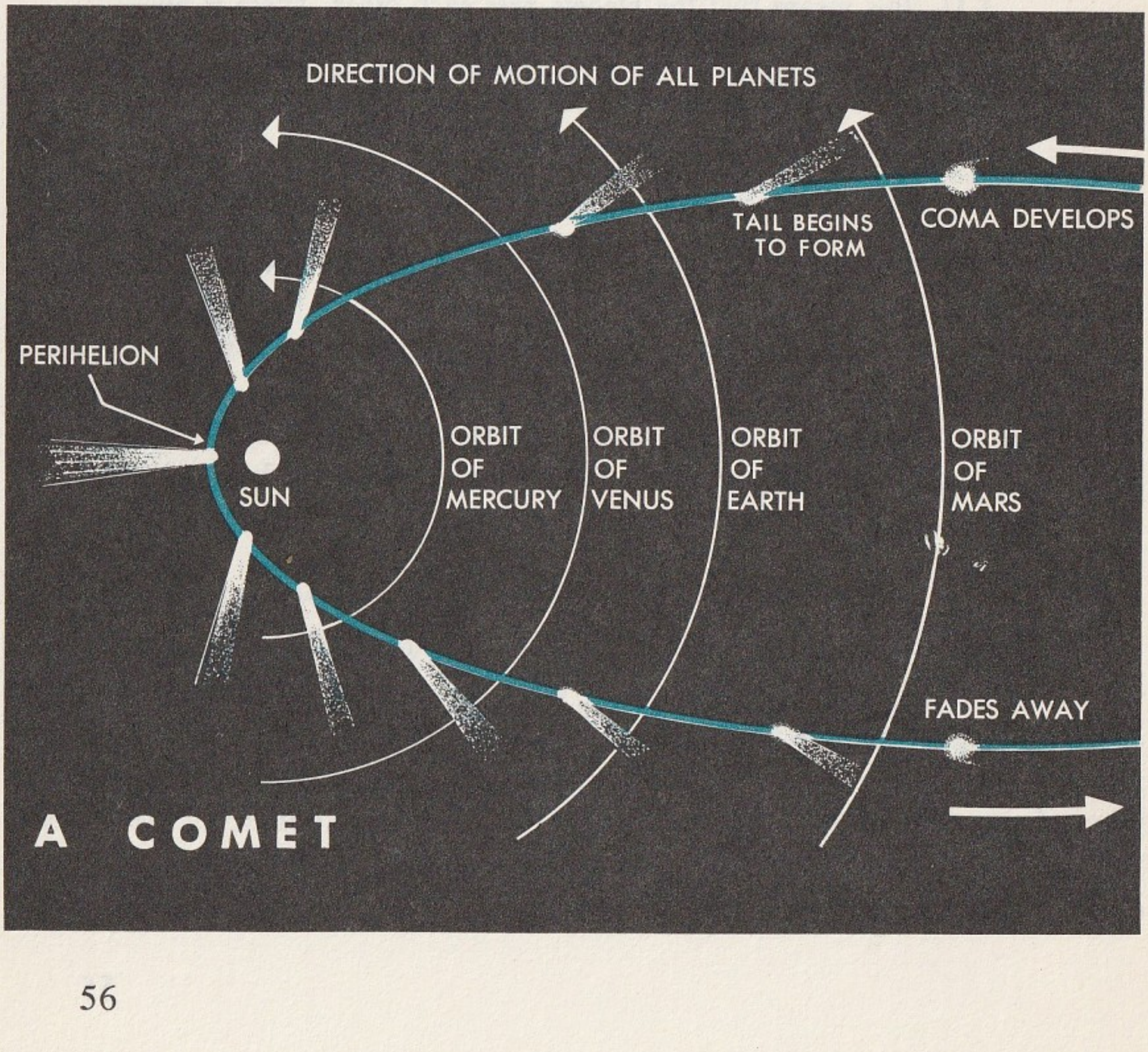
sun than Neptune, which, on the average, is thirty astronomical units from the sun.

Only a few years ago it was suggested that Pluto, now going around the sun as a planet, started out as a moon of Neptune. This would explain both Pluto's small size and its highly unusual orbit. And the real Planet *X* may still move undiscovered in the vastness of space beyond Neptune.

Comets Have Heads and Tails

UNTIL THE DRAMATIC APPEARANCE IN 1965 of the comet named Ikeye-Seki, after the Japanese who discovered it, most people on earth had never seen a large comet. The largest one before that appeared almost sixty years ago. But don't give up hope, because comets have a way of appearing without notice. In addition, the comet of 1910 will return in 1986. When it does return from its aphelion beyond the orbit of Neptune, this is what will happen:

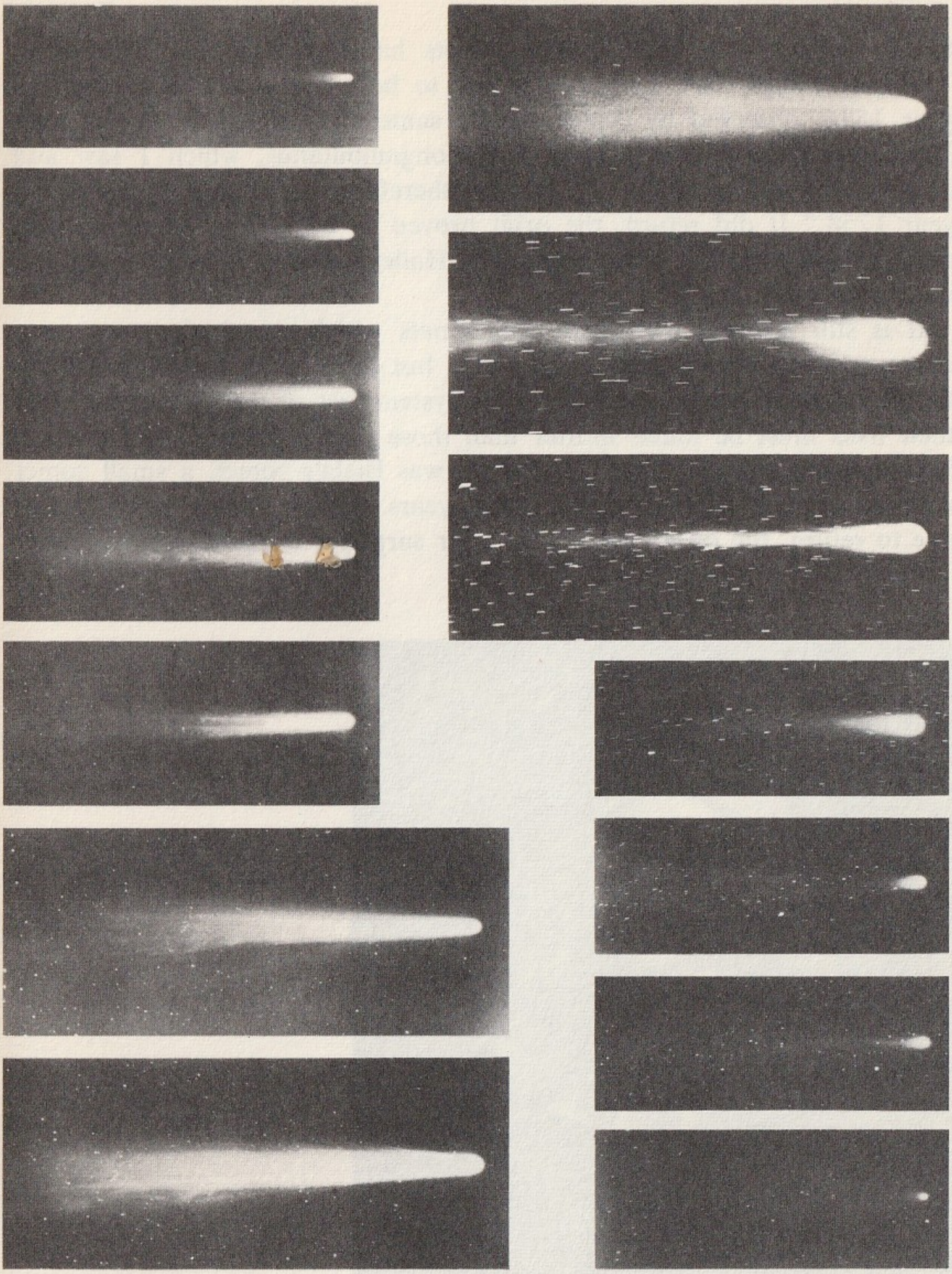
When the comet of 1910—it is known as Halley's comet and it moves retrograde—has crossed the orbit of Jupiter on its approach to the sun, it will probably be spotted, and an observer will report an "object" in such and such a position suspected to be a comet. When the comet nears the orbit of Mars its outlines will become fuzzy; astronomers will then be sure that it is a comet and will say that it "has developed a *coma*". The word *coma* here is the Latin word for "head of hair". At about the time it passes the orbit of Mars, it will grow a tail, and the tail will become longer as the comet moves closer to the sun. Always the tail will point away from the sun, even when the comet, having reached its perihelion, rounds the sun. Sometimes, at about that point, the tail breaks off and dissipates itself in space and usually the comet grows a new one which still points away from the sun, pointing ahead now, since the comet is moving away from the sun. As it recedes into



space both tail and comet grow dimmer and dimmer and finally disappear.

In the past large comets always excited a great deal of superstitious fear, mostly because their appearance could not be predicted. They were considered an evil omen; moreover they were thought to be poisoning our atmosphere. Even after astronomers knew that comets were actually far out in space, in the late sixteenth century, it was impossible to predict their appearance. It is still impossible to predict the discovery of new comets, although the return of periodic comets can be predicted.

In about 1700 an Englishman, Dr. Edmund Halley, began a study of orbits of comets, then believed to be parabolas or open curves. He saw

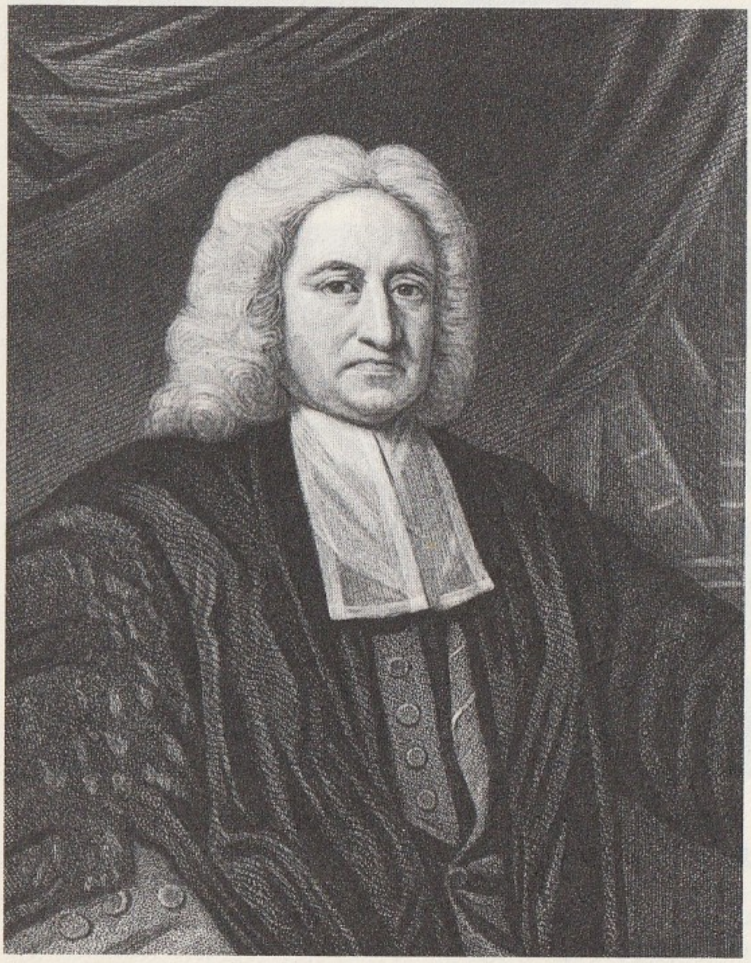


On 26 April, 1910, Halley's comet was photographed (*top left*) as its tail began to grow on its approach to the sun. On 6 May (*bottom left*) its tail was at its longest; on 23 May (*upper right*) the tail seemed to break off, and on 11 June (*bottom right*) the coma had faded almost completely away.

to his surprise that three bright comets had travelled the same orbit.

"Many things," he wrote, "lead me to believe that the comet of the year 1531, observed by Apian, is the same as that which, in the year 1607, was described by Kepler and Longomontanus, which I saw and observed myself in 1682. . . . I may, therefore, predict its return in the year 1758." It did return, the orbit proved to be a long ellipse instead of a parabola and the comet was given Halley's name. It keeps reappearing periodically.

It is still possible that there are comets which travel along an open curve and approach the sun only once, but most astronomers now think that comets are members of our solar system just as the planets are. But their lives must be much shorter than those of the planets. Astronomers have actually seen a comet "die". That was Biela's comet, a small comet with an orbital period of only a few years. At one time, when it was due to return, the observers saw to their surprise two small comets mov-



EDMUND HALLEY

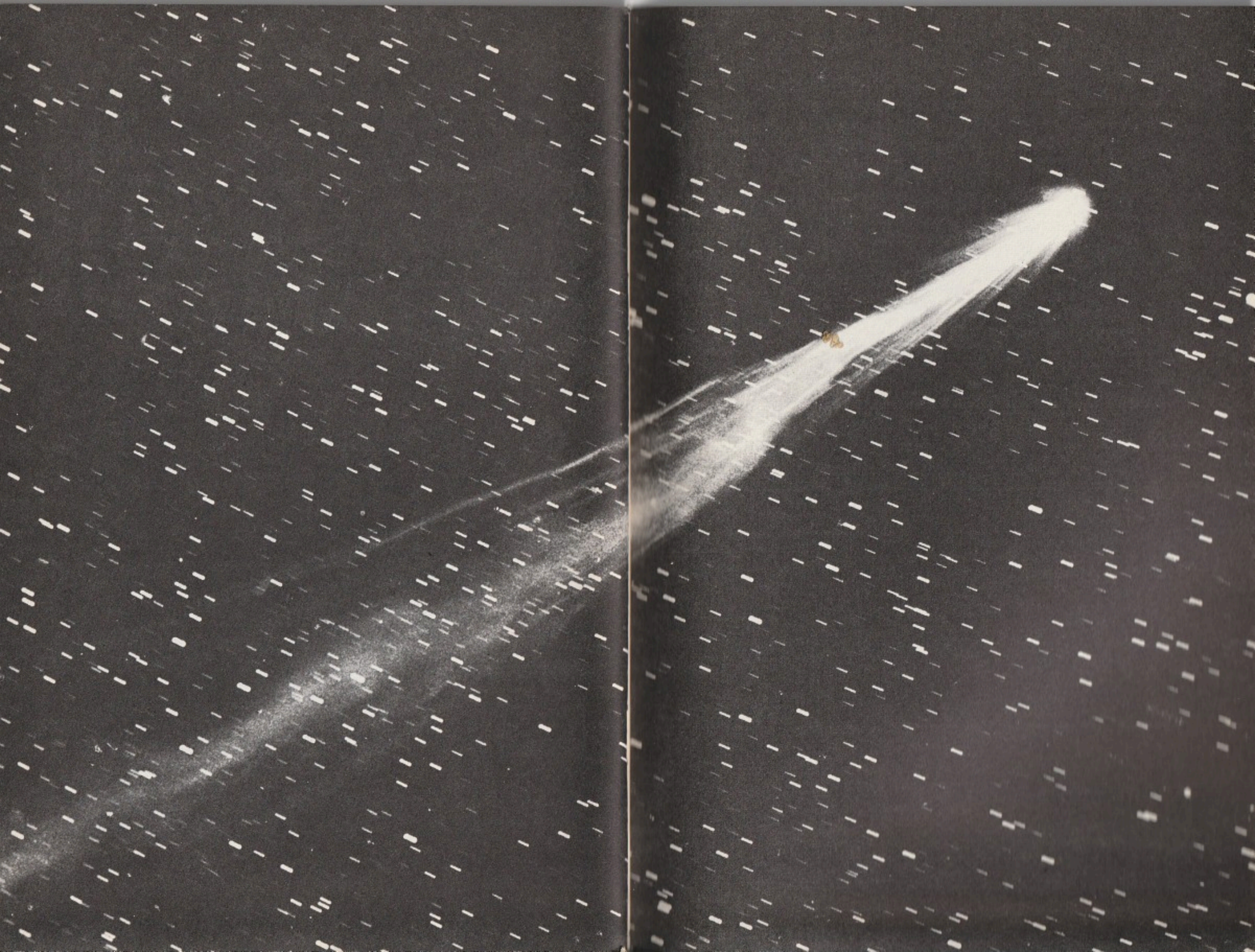
ing side by side. Next time Biela's comet did not return, but when the earth passed through its orbit, a shower of shooting stars was seen.

What Are Comets Made Of?

THIS EVENT MADE IT CLEAR that comets slowly dissipated in space, but it was not yet clear why they did. Slowly the idea formed that comets were not really solid bodies but just an accumulation of loose particles of dust, rocks and pebbles holding gases between them which formed the tail when near the sun. Fred L. Whipple of Harvard showed in about 1950 that loose matter could not trap enough gases for the formation of a tail, especially since that tail was sometimes lost.

So it was determined that it has to be the other way round, not solid pieces holding gases, but gases holding the solid matter. When far from the sun a comet consists of ices—frozen ammonia, frozen methane and frozen water. If you could see it close up, the comet would probably look like a dirty snowball several miles in diameter. As the comet comes closer to the sun these gases begin to evaporate, first forming the coma. Then, when the pressure of the light, heat and other

Next page: In 1908, an American astronomer, Daniel Walter Morehouse of Duke University, discovered a comet officially designated 1908 III. This remarkable photograph of Morehouse's comet was taken 16 November, 1908.



radiation from the sun becomes powerful enough, the gases are "blown away" from the comet's body to form its tail. This gas becomes visible with a great luminous effect.

Facts about our sun...

The sun is a G-type star, an average member of the Milky Way and situated about 30,000 light-years from the center of that galaxy.

Mass—2 billion billion billion tons, or 333,000 times that of earth
Diameter—865,000 miles, or 109 times that of earth
Distance from earth—92.9 million miles on the average
Surface temperature—about 11,000° Fahrenheit
Average density—1.41 times that of water
Speed of rotation on its axis—4,470 miles an hour; one turn each 25.3 days
Absolute magnitude—5, compared with other stars at a comparable distance
Apparent magnitude—26.9, as viewed from earth

...and our moon

Many scientists believe that the moon was created at about the same time and in about the same way as earth. It is the closest celestial body to earth.

Distance from earth—238,000 miles (221,000 minimum; 253,000 maximum)
Mass—74 billion billion tons, or about .0123 times that of earth
Diameter—2,160 miles, or about .27 times that of earth
Density—about 3.36 times that of water
Surface gravity—about one-sixth that of earth
Month (sidereal period)—27.3 days

JUPITER
URANUS
SATURN
MERCURY